TWIN CITY 60–90 TRACTOR PULLING TWELVE PLOWS

Automobile Engineering

A General Reference Work

FOR REPAIR MEN, CHAUFFEURS, AND OWNERS; COVERING THE CONSTRUCTION, CARE, AND REPAIR OF PLEASURE CARS, COMMERCIAL CARS, AND MOTORCYCLES, WITH ESPECIAL ATTENTION TO IGNITION, STARTING, AND LIGHTING SYSTEMS, GARAGE EQUIPMENT, WELDING, FORD CONSTRUCTION AND REPAIR, AND OTHER REPAIR METHODS

Prepared by a Staff of

AUTOMOBILE EXPERTS, CONSULTING ENGINEERS, AND DESIGNERS OF THE HIGHEST PROFESSIONAL STANDING

Illustrated with over Fifteen Hundred Engravings

SIX VOLUMES

AMERICAN TECHNICAL SOCIETY
CHICAGO
1921

Authorities Consulted

THE editors have freely consulted the standard technical literature of America and Europe in the preparation of these volumes. They desire to express their indebtedness, particularly, to the following eminent authorities, whose well-known treatises should be in the library of everyone interested in the Automobile and allied subjects.

Grateful acknowledgment is here made also for the invaluable co-operation of the foremost Automobile Firms and Manufacturers in making these volumes thoroughly representative of the very latest and best practice in the design, construction, and operation of Automobiles, Commercial Vehicles, Motorcycles, etc.; also for the valuable drawings, data, illustrations, suggestions, criticisms, and other courtesies.

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G.M.C. TRUCK EQUIPPED WITH FIRE FIGHTING APPARATUS

ILLINOIS SUPER-DRIVE TRACTOR PULLING FOUR OLIVER PLOWS

Foreword

THE period of evolution of the automobile does not span many years, but the evolution has been none the less spectacular and complete. From a creature of sudden caprices and uncertain behavior, it has become today a well-behaved thoroughbred of known habits and perfect reliability. The driver no longer needs to carry war clothes in momentary expectation of a call to the front. He sits in his seat, starts his motor by pressing a button with his hand or foot, and probably for weeks on end will not need to do anything more serious than feed his animal gasoline or oil, screw up a few grease cups, and pump up a tire or two.

¶ And yet, the traveling along this road of reliability and mechanical perfection has not been easy, and the grades have not been negotiated or the heights reached without many trials and failures. The application of the internal-combustion motor, the electric motor, the storage battery, and the steam engine to the development of the modern types of mechanically propelled road carriages has been a far-reaching engineering problem of great difficulty. Nevertheless, through the aid of the best scientific and mechanical minds in this and other countries, every detail has received the amount of attention necessary to make it as perfect as possible. Road troubles, except in connection with tires, have become almost negligible and even the inexperienced driver, who knows barely enough to keep to the road and shift gears properly, can venture on long touring trips without fear of getting stranded. The refinements in the ignition, starting, and lighting systems have added greatly to the pleasure in running the car. Altogether, the automobile as a whole has become standardized, and unless some unforeseen developments are brought about, future changes in either the gasoline or the electric automobile will be merely along the line of greater refinement of the mechanical and electrical devices used.

¶ Notwithstanding the high degree of reliability already spoken of, the cars, as they get older, will need the attention of the repair man. This is particularly true of the cars two and three seasons old. A special effort, therefore, has been made to furnish information which will be of value to the men whose duty it is to revive the faltering action of the motor and to take care of the other internal troubles in the machine.

¶ Special effort has been made to emphasize the treatment of the Electrical Equipment of Gasoline Cars, not only because it is in this direction that most of the improvements have lately taken place but also because this department of automobile construction is least familiar to the repair men and others interested in the details of the automobile. A multitude of diagrams have been supplied showing the constructive features and wiring circuits of the majority of the systems. In addition to this instructive section, particular attention is called to the articles on Welding, Shop Information, Electrical Repairs, and Ford Construction and Repair.

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DETROIT ELECTRIC AUTOMOBILE

Courtesy of Detroit Electric Car Company, Detroit, Michigan

GASOLINE TRACTORS

PART II

CONTROL SYSTEM

ENGINE GOVERNORS

Need of Governors. *Plowing.* In order that a tractor may be operated most economically, it must be capable of one-man control since, in plowing, conditions are continually encountered where the driver's attention must be centered on the management of the plows and the steering of the machine to the exclusion of everything else. Moreover the demands upon the engine are continually varying even when the soil conditions are apparently uniform for long stretches. Stones, roots, and extra heavy patches of sod all impose considerable extra load on the engine that can be met satisfactorily only by an automatically controlled throttle if a uniform plowing speed is to be maintained.

Belt Work. A far greater load variation is encountered in belt work than in plowing, as in the former the engine may be running practically idle at one moment and be almost choked down by overloading the next, whereas in the latter there is always a load on the engine and therefore the danger of racing is absent. Irregular speed under changing load, racing of the idle engine, and tardy opening of the throttle to meet the increased load, all of which are unavoidable with hand control, represent conditions of operation which not only reduce production at the machine being driven but are very bad for the engine itself as they result in overheating, prevent proper lubrication, and, not infrequently, result in burned-out bearings. In any case the provision of a governor on the engine releases a hand for other and more productive labor. The majority of tractors go into service in the hands of an unskilled operator, and unless there is a governor on the engine, his course of instruction is likely to be marked by the occurrence of more or less damage that automatic control would prevent.

Centrifugal Governors. Despite almost innumerable attempts to displace it, the centrifugal principle first taken advantage of more than a century ago to control the speed of a steam engine is still in almost universal use for this purpose. Most tractor engines are equipped with what is commonly termed a fly-ball governor, though the details of the mechanism and the character of the throttle valve it is employed to control differ more or less. In its simplest form such a governor consists of two weights on the end of oppositely placed arms which are pivoted on a spindle connected to the throttle valve, either directly or through suitable linkage, so that any movement of the weights is communicated directly to the throttle. On a stationary engine the governor may

Fig. 58. Simplex Engine Governor
Courtesy of Duplex Engine Governor Company, Brooklyn, New York

be placed upright and is not subjected to vibration or jolting, so that gravity alone may be depended upon to keep the weights in their normal position, but on the tractor springs are usually employed, and the governor may then be placed in any position. When running below a certain speed, either gravity or the pull of the spring is sufficiently strong to keep the weights together against the shaft or close to it. But as the speed increases, centrifugal force acts on the weights and tends to make them assume a position at right angles to the shaft. The faster the engine runs, the closer the weights approach to this position, but as their movement brings about a proportionate closing of the throttle, the engine is not given an opportunity to increase its speed. A well-balanced governor of this type will operate so sensitively that

there will be practically no perceptible change in speed between idling and full load. So far as the tractor is concerned, centrifugal governors are of two general types, those that are an integral part of the design of the engine and are built right into it and those that are in the nature of auxiliary devices designed to be attached to the inlet manifold between the carburetor and the intake valves.

Auxiliary Types. The Simplex governor, shown in Fig. 58, and the Pierce, illustrated in Fig. 59, are examples of governors designed to be adapted to any make of motor, the only modification necessary depending upon the details of the drive, since the governor must be driven directly from the motor itself. In the

Fig. 59. Section of Pierce Engine Governor
Courtesy of Pierce Governor Company, Anderson, Indiana

Simplex the governor weights, which are housed in the casing just under and to the left of the oil plug shown, operate a grid valve the openings of which appear in the intake manifold flange at the left. The driving attachment, designed in this instance for a flexible shaft drive, appears at the right. Fig. 60 shows the attachment of a Simplex governor to a Continental motor, the drive in this case consisting of a solid shaft and bevel gears operating from the camshaft. The governor is set for the maximum speed to which the motor on which it is mounted is best adapted and is then sealed, as shown at the left end. As the governor mechanism runs in a bath of oil, it requires no attention except to replenish the oil from time to time.

Fig. 60. Installation of Simplex Governor on Continental Motor of Bullock Tractor
Courtesy of Bullock Tractor Company, Chicago, Illinois

Fig. 61. Installation of Pierce Governor on Buda Motor
Courtesy of Pierce Governor Company, Anderson, Indiana

The Pierce governor, which is shown in horizontal section, operates a conventional butterfly type of throttle valve such as is used in the majority of carburetors. This valve is shown at the left, while the weights and the driving attachment are at the right. Between the two is the spring against which the centrifugal force of the revolving weights must act to close the throttle. Just above

Fig. 62. Built-In Governor of Creeping-Grip Tractor
Courtesy of Bullock Tractor Company, Chicago, Illinois

the left-hand end of this spring will be noted a screw adjustment by means of which the speed for which the governor is set may be altered. Increasing the tension of the spring by screwing this in permits an increase in the speed of the motor since the weights must then revolve at a higher speed in order to overcome the pull of the spring. This is the principle upon which the adjustment of

all centrifugal governors is based. One method of attaching the Pierce governor is illustrated in Fig. 61, which shows it mounted on a Buda motor and driven through bevel gearing from the camshaft.

Built-In Types. The part sectional end view of the engine of the Creeping Grip tractor, Fig. 62, illustrates an excellent example of a built-in governor. This is driven from a transverse shaft which takes its power through helical cut gearing from the timing gear of the motor, the same shaft also serving as the magneto drive. In expanding, the revolving weights draw in the sliding shaft shown, which is linked to a bell-crank lever at its outer end. The lever is attached to the throttle, which will be noted just to the right of the carburetor. This bell-crank lever is also attached by linkage to a dash pot to prevent the governor from "hunting," or "surging," as it is

Fig. 63. Governor and Magnetic Unit of Creeping-Grip Tractor Motor
Courtesy of Bullock Tractor Company, Chicago, Illinois

Fig. 64. Emerson-Brantingham Motor, Showing Governor
Courtesy of Emerson-Brantingham Company, Rockford, Illinois

variously termed, that is, fluctuating violently over a wide speed range. This governor is designed to control the speed of the motor between a minimum and a maximum of 400 to 700 r.p.m. and is adjustable by means of the hand lever shown in Fig. 63, which illustrates the combined governor and magneto unit before attachment to the motor.

In Fig. 64, which shows the complete power plant of the Emerson-Brantingham 12–20 tractor, is illustrated another type of built-in governor, the details of which are clearly shown. This governor is driven by a belt and is of the usual steam-engine type in which the weights are carried on leaf springs, the movement being transmitted to the throttle through the linkage shown.

TRACTOR CLUTCHES

Functions of Clutches. Since the internal combustion motor cannot be started under load and will stall if the load be applied too suddenly, even though the engine is developing its full power, it is necessary to employ a means of picking up the load gradually as well as of connecting or disconnecting the motor from the load as desired. This means is the clutch; and clutch problems on the tractor are the same in kind but greater in degree than those encountered on the automobile since the load to be started is so much greater. An automobile need start its own weight only and in doing so it encounters but slight rolling resistance, whereas the tractor must not only get a very much greater weight under way but in starting it must overcome the far greater resistance represented by the plows or other load and also that of the ground itself.

As a general rule the types of clutches employed on tractors are the same as those used on automobiles, but they are given a considerably increased area of contact surfaces and these surfaces are held together under much higher spring pressures in order to carry the heavier load. Regardless of its type, the principle of the friction clutch is based upon holding the driving surface (directly connected to the motor) and the driven surface (directly connected to the transmission or speed reduction gear) in contact under a pressure per square inch that is greater than that exerted by the engine in carrying the load. When the pressure required

to carry the load exceeds that exerted by the clutch spring, the contact surfaces slide upon one another and the clutch is said to *slip*. Unless this slipping took place, some one of the links in the transmission between the wheels or tracks and the engine would have to give way or the engine itself would be stalled by the load. It is accordingly the function of the clutch to slip, first, to insure gradual engagement in picking up the load and, second, to prevent damage to the transmission or the motor when the load becomes excessive. The latter function, however, is more important in theory than in practice since an excessive load almost

Fig. 65. Transmission Unit of Illinois Tractor Showing Multiple-Disc Clutch
Courtesy of Illinois Tractor Company, Bloomington, Illinois

invariably stalls the motor before the clutch begins to slip, unless its surfaces have become glazed through wear or its spring has weakened.

Types of Clutches. In practically every case the flywheel of the motor itself forms the driving member of the clutch. The driven member may be a cone faced with asbestos-wire fabric, a plate faced with similar friction fabric, or a contracting band similarly faced which is mounted so as to contact with the rim of the flywheel itself or with that of a smaller drum attached to the flywheel; or friction-faced shoes may be arranged to expand against the inner face of the flywheel. The moving force in every case is the clutch spring. In the order mentioned, these types are known as the cone, plate, contracting-band, and expanding-band,

or expanding-shoe, clutches. Where a greater contact area is desired than is afforded by the diameter of the flywheel, a series of plates or discs is employed. These plates are divided into two groups, one of which is carried on spindles or bolts attached to

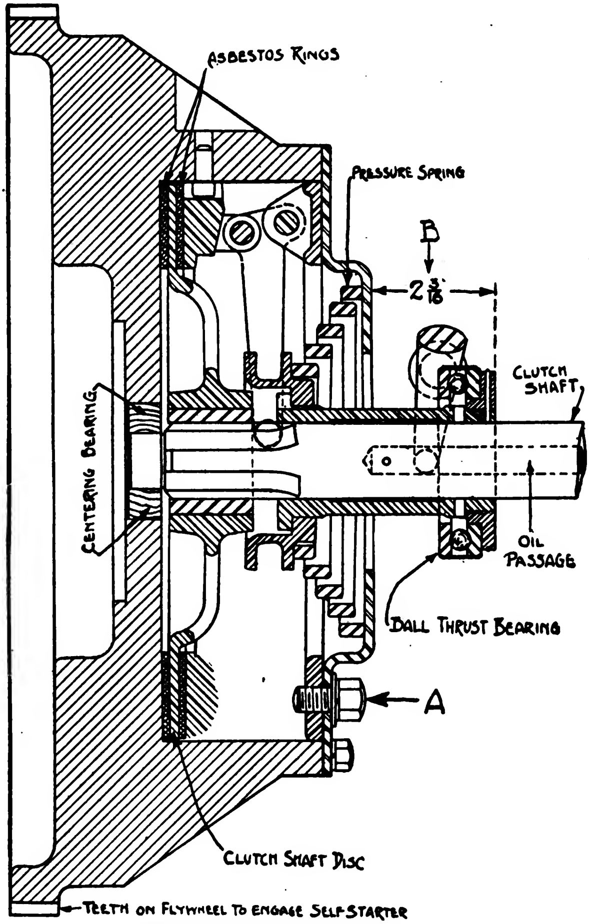


Fig. 66. Section of Dry-Plate Clutch As Used on Moline Tractor
Courtesy of Moline Plow Company, Moline, Illinois

the flywheel and forms the driving member, while the second group is similarly mounted on members attached to the clutch shaft and forms the driven member. When in engagement, the two groups are pressed together by the clutch spring in the same manner as in other types of clutches. This clutch is known as the

multiple-disc type, and in some instances it operates in a bath of lubricating oil, the latter being squeezed from between the plates as they come in contact, thus ensuring gradual engagement. In Fig. 65 is shown the multiple-disc clutch of the Illinois tractor, the clutch being the small group of plates shown at one end of the transmission unit.

Plate Type. The sectional diagram, Fig. 66, not only serves to illustrate the details of the dry-plate clutch but also makes clear the principles of clutch operation. This is the Borg and Beck clutch as used on the Moline tractor. One of the asbestos

Fig. 67. Main Clutch of Holt Caterpillar Tractor
Courtesy of Holt Manufacturing Company, Inc., Peoria, Illinois

rings shown is attached to the flywheel, while the second ring is carried on the driven clutch member, while between the two is the clutch disc, which is a ring or disc of steel also attached to the clutch shaft. By means of the collar and toggle levers which multiply the force exerted by the spring, this clutch disc is clamped between the two asbestos rings when the clutch is engaged. The backward pressure, or reaction of the spring, is taken on the ball thrust bearing shown, this being an essential of all types of cone or plate clutches since otherwise this back pressure of the spring would cause considerable frictional resistance to the revolution of

the clutch shaft. The screw marked *A* is an adjustment to maintain the distance *B* indicated, this distance being necessary for the complete release of the clutch when disengaged.

Expanding-Shoe Type. The Lauson tractor clutch affords an example of the expanding-shoe type which calls for very little

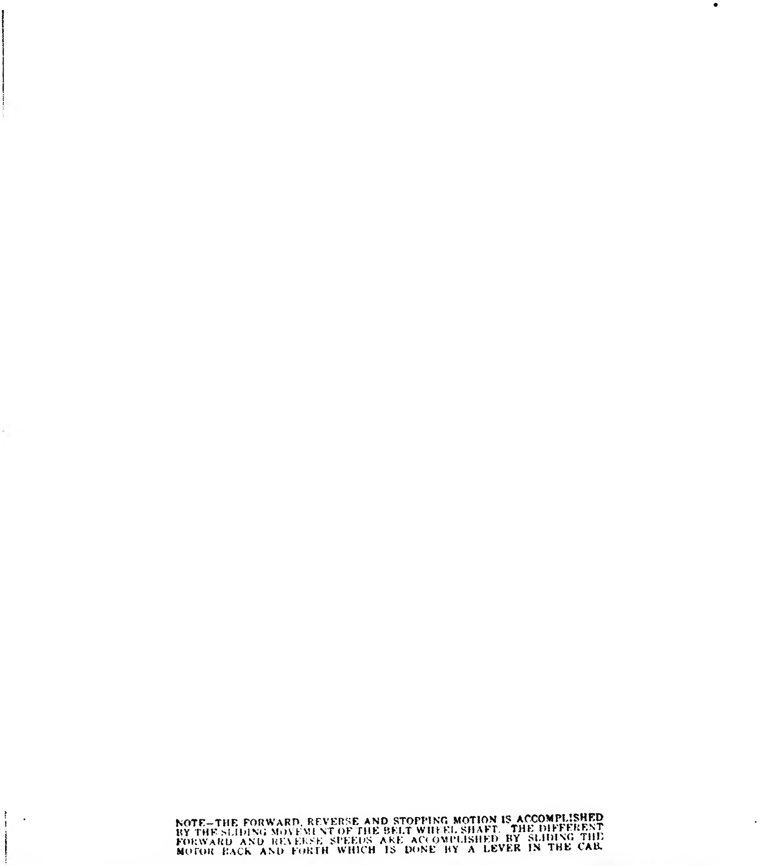


Fig. 68. Friction Transmission of Heider Tractor
Courtesy of Rock Island Plow Company, Rock Island, Illinois

explanation. Against the inner face of the flywheel are two pivoted shoes which are counterbalanced. These shoes are faced with asbestos brake lining and are designed to be held in contact with the inner face of the flywheel rim by means of the toggle mechanism shown. The spring has the same location as in other

types of clutches, while its purpose, like that of other clutches, is to hold the clutch friction surfaces together under a pressure greater than that exerted by the engine in driving the tractor under load. The main clutch of the Holt caterpillar tractor is of a similar type, Fig. 67.

Contracting-Band Clutch. Neither the contracting-band nor the cone clutch calls for much description. The contracting-band clutch is practically a duplicate of the usual brake mechanism in which a friction-lined band is pressed against a revolving drum to bring the latter to a stop. In the case of such a clutch the object is to bring the contracting band to a stop on the drum, which is

Fig. 69. Bevel Friction Transmission of Square Turn Tractor
Courtesy of Square Turn Tractor Company, Norfolk, Nebraska

the flywheel, so that both the band and the flywheel revolve together, this really being the only difference between the brake and the clutch mechanism. The contracting band is attached to the clutch shaft, or driven member, and when in operation, revolves with it, thus carrying the load. This clutch is used in connection with a planetary type of transmission and is accordingly familiar through its employment on many thousand Fords.

Cone Clutch. In the cone clutch the inner face of the flywheel is turned to a bevel of approximately 30 degrees to form the driving member into which a cone-shaped member with the same bevel and lined with asbestos or other friction facing is

pressed by the spring. Owing to the necessarily limited area of friction contact in this type of clutch, a high spring pressure is necessary where a heavy load must be transmitted.

On the automobile this spring pressure is very much less than on the tractor owing to the slight resistance encountered by the machine in starting, so that the clutch may readily be disengaged with the foot through the medium of a short lever and pedal, but on any tractor except a very light one the effort required to do this would be excessive. The usual method of clutch operation on the tractor is accordingly by means of a long hand lever provided with a ratchet or locking detent, so that the clutch may be held out of engagement. Since it does not benefit the spring to keep it compressed, the clutch should not be locked out of engagement any longer than is necessary to shift the transmission gears to neutral, when the clutch should again be allowed to engage. Holding the clutch out of engagement overnight or while the tractor is standing in the field subjects the clutch spring to abuse and will soon result in weakening it to the point where the clutch slips whenever any extra load comes on it.

Friction Drive. While all the types of clutches mentioned are, in a sense, a friction drive in that friction is depended upon to transmit the power, the so-called friction drive is one in which the load transmitting members revolve independently of one another except for a single point, or line, of contact. This is made clear by the illustration of the friction transmission of the Heider tractor, Fig. 68. The flywheel is the driving member, as usual, but in this case its entire outer rim is covered with a special friction facing consisting of hard fiber. The flywheel rotates between two large steel discs, either one of which may be pressed against it. In this instance the left-hand disc is used for forward movement and the right-hand disc for backing, or reverse. It is also apparent that the point at which the flywheel makes contact with the disc determines the speed at which the latter and the tractor itself are driven.

In the position shown the tractor speed will be the lowest provided, since the flywheel is in contact with the outer edge of the disc, so that the relation of the two is that of a small gear to a large one and the speed of the latter is reduced. As the fly-

wheel moves toward the center of the driven disc, the relationship between the two becomes that of driving and driven gears which approach closer and closer to the same size, so that the speed of the driven member is increased. This movement of the flywheel is accomplished by mounting the motor itself on slides on the frame and moving it backward or forward by means of a large hand lever. The direction of movement of the tractor depends upon which disc is pressed against the flywheel.

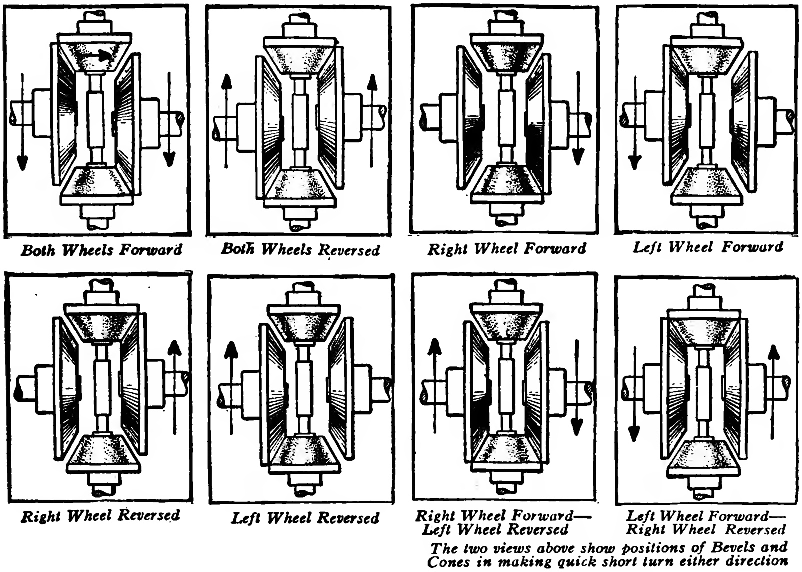


Fig. 70. Details of Operation of Bevel Friction Transmission
Courtesy of Square Turn Tractor Company, Norfolk, Nebraska

Bevel Friction Drive. The form of friction drive employed on the Square Turn tractor is shown in Fig. 69. In this drive the principle is exactly the same as already outlined, except that friction-faced (fiber) conical members take the place of the fly-wheel as the driving member and corresponding cones of iron are the driven members. The design is also modified to permit of driving either rear wheel independently or both in different directions at the same time in order to turn short corners. The small diagrams showing the different relations in which the driving and driven members may be placed, Fig. 70, explain the operations much better than a description. A separate hand lever controls

each of the driven discs, or traction members. Moving both of them forward drives the machine ahead through both driving wheels; pulling them back reverses the movement; and each may be used independently, so that one drives forward while the other is backing, thus turning the machine as if on a pivot.

TRACTOR TRANSMISSIONS

Speed vs. Weight. The power generated in an engine, whether by the expansion of steam or that of the ignited gases in an oil engine, is converted into mechanical energy by applying it to the movement of weight, and the power itself is represented by the extent of that weight and the number of times per minute that it is moved. Hence, for a given power the slower the speed at which the engine runs, the heavier must be the weight moved since it is set into movement a smaller number of times per minute. By increasing the speed, or number of impulses per minute, the weight moved can be correspondingly reduced. This fact explains why 25 hp. may be generated by a single cylinder stationary gas engine running at 250 r.p.m. or by a four-cylinder motor running at 1000 r.p.m. and why one motor is scarcely more than one-eighth the size of the other, although their power output is the same. The single cylinder engine will weigh 2 tons or more and will have flywheels of large diameter weighing more than the total weight of the smaller engine, but both move the same amount of weight per minute.

Automobile Practice. On the automobile the object of the designer is to keep the total weight down as much as possible consistent with reliability, so that light high-speed motors running up to 2000 r.p.m. or higher are employed. Such motors are practical for automobile use because the speed ratio between the driving and driven members—the motor and the rear wheels—is not excessive despite the high speed of the motor.

Tractor Practice. But on the tractor, where the maximum speed in plowing cannot exceed three miles per hour and is preferably less than that ($2\frac{1}{3}$ miles per hour is recommended by the Society of Automotive Engineers and most tractors are designed to plow at $2\frac{1}{2}$ miles per hour), the higher the speed of the motor, the greater the number of steps required in the gear reduction, and each step represents a loss of power in friction as well as addi-

tional parts to wear out. Since the tractor is not subject to the same weight limitations as the automobile, there is no advantage in employing a light high-speed motor. Generally speaking, the slower the speed of the motor consistent with the avoidance of excessive weight, the better adapted it is to tractor use. The slow-speed motor running at 450 to 750 r.p.m. also has the further advantage of subjecting its moving parts to less rapid wear in service and, other things being equal, should require less attention to keep in satisfactory running condition.

Function of Transmission. In the section on tractor motors it has been pointed out that the types in general use belong to two distinct classes: those which have developed with the stationary engine as a basis; and those that are an outgrowth of automobile practice. In either case the engine will only develop its normal rated power when allowed to run steadily at a rate close to its maximum speed. A gear reduction must accordingly be interposed between the motor and the driving members of the tractor; the speed of the motor determines how great this reduction must be, while the space and the limit of weight available determine what form it will take. Whether consisting of a compact unit such as is used on the automobile or of large pinions and gears occupying the entire space between the frame members of the tractor, this speed reducing mechanism is usually termed the transmission. This name includes everything between the clutch and the final application of the power to the wheels or the tracks, which is termed the final drive.

Wide Range of Types. Since tractor motors differ so widely, there is naturally a correspondingly wide range of types of transmissions, the latter varying all the way from what is practically a duplicate of the gear train used on heavy steam tractors, or road rollers, to the light and compact gear box used on high-speed automobiles. A few illustrations of typical examples of each class will suffice to give an idea of how widely this feature of the tractor varies on different designs. In comparing these, it should be borne in mind that while increased width of gear face affords a larger wearing surface to carry the load and large gear diameter means fewer steps in the reduction, these advantages may be offset by the exposure of the gears to dirt and mud.

The great differences in size and weight, in many cases where the same amount of power is to be transmitted, are accounted for by a similarly great difference in the character of the materials used. Small pinions and gears running at high speeds must be made of alloy steels, hardened and toughened by heat treatment, and must be run in a bath of oil. Large broad-faced gears, on the other hand, may be made of steel castings or even cast iron, and it is the usual practice to run them to a great extent without protection.

Speeds. Since the speed range of the average farm tractor is necessarily very low, its requirements are usually covered by the provision of but two forward speeds and one reverse. A few machines are provided with three speed transmissions, but this is the exception and is due to the use of either a high-speed motor or an automobile-type transmission. On low gear, which is equivalent to a forward speed of about one mile per hour, the speed reduction between the motor and the driving wheels of the tractor may range all the way from 40–1 to 80–1, that is, the motor makes 80 revolutions to a single turn of the driving wheels in the second case mentioned. Such a great difference between the motor speed and that of the machine itself necessitates a number of gear reductions, each one of which involves a power loss in itself and also presents an extra wearing surface that needs replacement sooner or later. Generally speaking, the lower the speed of the motor consistent with the avoidance of excessive weight, the less loss there will be in the transmission of the power to the rear wheels or tracks, as the case may be. The point below which it does not pay to reduce the motor speed appears to line between 400 and 500 r.p.m., as beyond that the weight increases all out of proportion to the advantage gained, while the upper limit lies between 700 and 800 r.p.m.; that is, a low-speed motor would govern between these limits, say 450 to 750 r.p.m., and its transmission would be designed to take care of the difference between 750 r.p.m. and the number of turns per minute made by the driving wheels, which would depend upon their diameter.

A high-speed motor, on the other hand, would run at 1000 to 1200 r.p.m. and its power would fall off very rapidly the moment its speed dropped below 800 r.p.m. To avoid an excessive number

of gear reductions, the driving wheels of a tractor equipped with a high-speed motor would usually be made comparatively small,

Fig. 71. Friction Drive of the Port Huron 12-25 H.P. Farm Tractor
Courtesy of Port Huron Engine and Thresher Company, Port Huron, Michigan

which is a disadvantage since such a tractor is constantly climbing the grade formed by its small wheels sinking into soft earth, or depressions, and is accordingly expending a large fraction of its

Fig. 72. Plan View of Avery Transmission
Courtesy of Avery Company, Peoria, Illinois

power in lifting itself rather than in driving ahead. It does not necessarily follow that a tractor equipped with a high-speed motor always has small driving wheels, since the reduction in speed required may be taken care of in the final drive.

Heavy Types. Those transmissions which, as already mentioned, represent a continuance of the practice followed for years on heavy steam tractors and road rollers are known as heavy types. Such a transmission is shown in Fig. 71, which gives a plan view of the Port Huron 12–25 friction-driven tractor. It also affords an example of a tractor with a comparatively high-speed engine equipped with large driving wheels. There are three gear reductions in all: the first will be noted at the left; the second is from this transverse shaft to a central gear on a shorter transverse shaft which also carries two small pinions meshing with the bull

Fig. 73. Transmission and Differential of 75 HP. Tracklayer Tractor
Courtesy of C. L. Best Gas Tractor Company, San Leandro, California

gears. Ordinarily the bull gears are attached directly to the driving wheels, but in that location it is difficult to protect them, while in the present design they are completely encased.

Since a tractor must make very short turns and both wheels must be driven when going straight ahead, a differential is indispensable. When rounding a short turn, it will be evident that the wheel on the outside of the curve must travel a much greater distance than that on the inside and that if both were driven at an equal speed, one would be forced to slip and impose a heavy strain on the machine. If the ground condition were such that the wheel would not slip, rounding the turn would be difficult.

In the Port Huron tractor illustrated the differential is located in the second transverse shaft which carries the pinions meshing with the bull gears. As changes in speed are effected through the friction drive, the gears of this transmission are constantly in mesh.

The Avery transmission shown in Fig. 72, is another example of the heavy type, the illustration showing the relation of the horizontal motor to the transmission. The two forward speed reductions are represented by the two pinions of different sizes carried directly on the crankshaft of the motor, while the reverse speed is the pinion just forward of these. The transverse shaft just under the rear end of the motor embodies the differential the housing of which will be noted at the right. This shaft also carries the pinions meshing with the bull gears. The complete power plant is carried on a sliding frame, and the different speed changes are effected by moving the motor so as to bring the different pinions into mesh with the large gear carrying the differential.

Fig. 74. Cotta Automobile Transmission of Dog-Clutch Type As Used on Four-Drive Tractor
Courtesy of Cotta Transmission Company, Rockford, Illinois

Intermediate Types. Between the heavy types just described and what is practically a motor-truck transmission, there are a number of transmissions that conform to some degree with automobile gear-box practice but are built on much heavier lines, for example, the transmission of the Best 75 hp. tracklayer type tractor shown in Fig. 73. Sliding gears are employed for the speed changes, and a bevel pinion and driving gear on the counter-shaft which incorporates the differential, the internal bevel gear of which shows plainly in the illustration. A typical automobile-type transmission is the Cotta, Fig. 74, as used on the Four Drive tractor.

Fig. 75. Transmission and Spring Drive Differential of 16-30 Oil-Pull Tractor
Courtesy of Advance-Rumely Thresher Company, Inc., Laporte, Indiana

Fig. 76. Transmission of Turner Tractor
Courtesy of Turner Manufacturing Company, Port Washington, Wisconsin

A clearer view of the details of the mechanism of a differential is shown in Fig. 75, which illustrates the Rumely 16–30 transmission. One of the features of this differential is the use of a series of eight springs for taking up the shock of starting which will be noted just inside the large gear. Upon engaging the clutch, these springs must first be compressed before the load falls upon the gear teeth, thus cushioning the latter. Other similar transmissions are the Turner, Fig. 76, the Hart-Parr, Fig. 77, and the Nilson, Fig. 78.

Fig. 77. Transmission of Hart-Parr Tractor
Courtesy of Hart-Parr Company, Charles City, Iowa

Special Types. In Fig. 79 is shown a plan view of the transmission of the Twin City 25–45 tractor, a feature of which is the use of toothed, or *dog*, clutches, the details of which are clearly shown. This view also shows the contracting-band clutch used on this machine. The dome just to the right of and forward of the flywheel houses the engine governor. Automobile practice is closely approached in the Yuba transmission, Fig. 80, and in the Holt caterpillar transmission, the gear box of the 10-ton Holt

Fig. 78. Transmission of Nilson Tractor
Courtesy of Nilson Tractor Company

Fig. 79. Contracting-Band Clutch and Transmission of Twin City Tractor
Courtesy of Minneapolis Steel and Machinery Company, Minneapolis, Minnesota

Fig. 80. Dual Automobile Type Transmission of Yuba Tractor
Courtesy of Yuba Manufacturing Company, Marysville, California

Fig. 81. Transmission of 10-Ton Holt Caterpillar
Courtesy of Holt Manufacturing Company, Inc., Peoria, Illinois

Fig. 78. Transmission of Nilson Tractor
Courtesy of Nilson Tractor Company

Fig. 79. Contracting-Band Clutch and Transmission of Twin City Tractor
Courtesy of Minneapolis Steel and Machinery Company, Minneapolis, Minnesota

Fig. 80. Dual Automobile Type Transmission of Yuba Tractor
Courtesy of Yuba Manufacturing Company, Marysville, California

Fig. 81. Transmission of 10-Ton Holt Caterpillar
Courtesy of Holt Manufacturing Company, Inc., Peoria, Illinois

tractor being shown in Fig. 81. Both these types are of the selective sliding-gear type generally used in automobiles, the Yuba

Fig. 82. Worm Drive of Sandusky Tractor
Courtesy of Dauch Manufacturing Company, Sandusky, Ohio

Fig. 83. Transmission of Huber Light Four Tractor
Courtesy of Huber Manufacturing Company, Marion, Ohio

transmission clearly showing the individual clutches which are used in the tracklaying machine to enable the operator to drive either track separately when turning. A feature taken directly

from automobile practice is the use of the worm drive, Fig. 82. The Huber, Fig. 83, is a type that is in a class by itself. Its details and method of operation are clearly indicated in the illustration.

Final Drive. As in the case of the automobile there is a further speed reduction between the engine and rear wheels in the final drive, but as the speed reduction between the tractor engine and its driving members, whether the latter be wheels or tracks, is so great, this cannot take the form of a small pair of bevel

Fig. 84. Sectional View of Emerson-Brantingham Company Transmission, Showing Oil Level
Courtesy of Emerson-Brantingham Company, Rockford, Illinois

gears. The usual method is to employ bull gears, or internal gear rings of large diameter which are bolted to the driving wheels and with which small pinions on the ends of the transverse shafts of the change-speed gear mesh. In some instances automobile practice is followed by using a live axle. This is a combination of a sliding change-speed gear of the selective type with a planetary gear. The sectional view of the Emerson-Brantingham transmission, Fig. 84, clearly shows the relation of the selective sliding gears and the oil level necessary for lubrication.

Fig. 85. Details of Final Drive, or Track of Holt Caterpillar Tractor
Courtesy of Holt Manufacturing Company, Inc., Peoria, Illinois

Fig. 86. Final Drive of C. L. Best Tracklayer Tractor
Courtesy of C. L. Best Gas Tractor Company, San Leandro, California

Fig. 87. Details of Final Drive of Yuba Ball-Tread Tractor
Courtesy of Yuba Manufacturing Company, Marysville, California

Final drive in tracklaying machines is usually through large sprockets on the ends of the transverse shaft, these sprockets meshing in the track itself. The track runs on rollers or balls and passes around an idler at the end of the tread, this idler being made adjustable so as to vary the tension on the continuous track. The details of the Holt caterpillar, the Best tracklayer, and the Yuba ball-tread machines of this type are shown in Figs. 85, 86, and 87, which make the principles of operation so clear that further explanation is unnecessary.

Only a brief mention has been made of a few of the different types of transmissions and final drives employed on tractors, there being so many that it would be out of the question to attempt to describe all of them, particularly since not a few have numerous special features. The foregoing examples, however, cover the principles employed in practically all tractor transmissions and suffice to make clear the manner in which these principles are applied.

TRACTOR OPERATION

GENERAL INSTRUCTIONS

Tractors Different in Design but Alike in Care Required. In the foregoing pages an attempt has been made to outline briefly the principles of tractor operation with just sufficient references to actual types to make the text clear. At the present stage of development it is hardly possible to select any one manufacturer's product as typical of tractor design in general or as embodying throughout those features of design which are most likely to become standardized during the next five years of development. There are so many different makes on the market and frequently so many models of each make that it would require a volume larger than the present one merely to give a brief description of all of them. Consequently, no extended descriptions of any tractors are given here.

While designs and details of construction differ so widely and so frequently, all oil or gas engine tractors are based on certain underlying principles and all call for the same kind of care. The remainder of this article is accordingly devoted to an outline of the methods of handling tractors in service with a

view to pointing out clearly just the kind of care the machine needs to keep it running efficiently. To facilitate reference, this information is put in the form of questions and answers grouped under the particular subjects which they cover.

Degree of Care Necessary. Before taking up the detailed consideration of tractor operation it is well to revert for a moment to the comparison between the automobile and the tractor in order to emphasize the great difference in the conditions of operation of the two. It is a great mistake for the owner or operator of a tractor to conclude that because he can keep his car running for weeks at a time and subject it to the severest kind of service without being called upon to give it more than passing attention at infrequent intervals, the same amount of care will suffice to keep the tractor running equally well. The most severe service to which an automobile can be subjected is trifling compared to what a tractor must undergo in plowing ten hours a day. No comparison between the two is possible. The attention demanded in running a tractor is really only comparable to that required by a marine engine which is run steadily at full power.

It is naturally impracticable to employ more than one man to run the average tractor so that the single operator must assume the combined tasks of the oiler, engine-room attendant, and engineer on watch in the engine room of a steamer. He must see that every part is constantly lubricated, must watch all moving parts in sight from time to time and keep all his senses on the alert all the time to detect the first indications of overheating or faulty operation as evidenced by the sounds produced.

Parts Giving Most Trouble. Over two thousand tractor owners sent in reports in answer to a questionnaire forwarded to them by the Department of Agriculture. In answer to the question "What part of your tractor gives you most trouble?" more than seven hundred mentioned some part of the motor and of that number considerably over one-half gave the ignition as the chief source of delay. A leading tractor manufacturer substantiates this by stating in his instruction book that the motor is responsible for fully 75 per cent of all tractor troubles and that

70 per cent of the motor trouble is due to the ignition. A resumé of the answers sent in to the questionnaire follows:

Magnetos	299	Cylinders and pistons	61
Spark plugs	110	Clutch	59
Gears	108	Valves and springs	43
Carburetor	104	Lubrication	29
Bearings	80	Starting	28

The figures given in each case represent the number of tractor owners who gave the part in question as the chief cause of their troubles in operation. These figures do not, however, give any idea of the relative importance of the parts as sources of trouble. Failure of the magneto, or even of a spark plug, brings the tractor to a halt, but the trouble may usually be remedied in a very short time and no damage is caused, whereas a breakdown due to faulty lubrication, or to the failure of the cooling system, which is not mentioned at all, will usually involve the loss of anywhere from a day to a week besides a heavy repair bill.

Supply of Spares Necessary. The cost of an ample supply of spare parts is small compared with the time that is saved when the part most needed is right at hand and can be installed without delay, so that a number of spares of the most necessary parts should be considered part of the investment and be bought at the same time as the machine. Unless it be an ocean-going steamer, there is hardly another piece of machinery that performs such strenuous service so far from a repair and supply base as does the tractor. It would be just as foolish for the chief engineer of a steamer to leave port without any spare parts in the storeroom and still expect to arrive at his destination, regardless of what happened, as it is for a farmer to purchase a tractor and expect to get through his first, second, or any other season of plowing or threshing without vexatious delays unless he has on hand spares of the parts most frequently needed.

Manufacturer's Service Poor. While it would not be just to generalize by saying that the service rendered the purchaser by every manufacturer of tractors is poor, this is true in many cases and must always remain so for the farmer who is located miles from the nearest dealer representing the factory. It is nothing unusual to waste from half a day to a day, telephoning and

waiting for a part to be sent out or driving in for it. The dealer may be off for the day in some other part of the county, making a demonstration or closing a sale, and there may be no one in his place of business to render the desired service. Meanwhile, the machine is standing idle. There are few replacements that the experienced driver of a tractor cannot make without other assistance than that provided by the usual farm shop, so that if the parts are on hand little time will be lost in getting the machine under way again.

Parts Needed. While the make of the tractor in question will determine the character of many of the spares that should be carried by its owner, there are some that are needed with all makes. These are valves, valve springs, and small parts needed in connection with the valves, ignitors, or make-and-break plugs for low-tension ignition systems, also ignitor trip rods, or rather the small parts which compose the fittings of the rod rather than the rod itself, since the latter is not subjected to wear. Spare connecting cables cut to length and fitted with terminals, whether for high- or low-tension systems, will often be found valuable. Extra fan belts and spark plugs should hardly be called spare parts in this connection since they are absolute necessities at comparatively short intervals. Hose connections between the motor and the radiator are also in the same class. Where a motor is equipped with die-cast main bearings or connecting-rod bearings, a spare set will often prove to be worth many times its cost in the saving of plowing or threshing time, since even well-attended machines do suffer breakdowns from burnt-out bearings at times. Extra piston rings as well as an extra piston and a connecting rod are likely to be called for sooner or later. The magneto is a pretty expensive piece of equipment and, moreover, it is usually so reliable that it will continue to work season after season without giving any trouble. But when it does break down, it is sometimes beyond the ability of the tractor operator to make the repair. Where two or more tractors are operated on a farm and the same magneto is standard on all of them, it would pay to invest in a spare, though at any time but the height of the season the laying up of one tractor would probably not cause any trouble.

The foregoing discussion has been confined to enumerating motor parts or accessories that should be carried as spares since they are common to practically all motors. So far as the rest of the machine is concerned, the owner must either learn from experience what parts are likely to wear out rapidly and need replacement at short intervals, or he must depend upon the manufacturer's representative to give him this information. Naturally, the maker and his salesmen do not wish to give the impression that any of the machine's parts will need replacement in a short time, and in a good many instances they are as much in the dark as the purchaser is, since it may be that the model has just been placed on the market and there has been no opportunity to learn its weak points in actual service.

Both the time spent in getting information of this kind and the money invested in the necessary spare parts will return very substantial dividends when the occasion arises to use the parts. There are some parts that may never be used, such as a steering knuckle. Get the manufacturer's representative to give you a frank opinion. Point out your position, when isolated, and do not content yourself with his first recommendations. Insist on finding out what are the weak parts of every important unit. The factory man has a good line on this by the extent of the demand for certain replacement parts. It will usually be found a paying investment to purchase a stock of almost all of them rather than take chances on getting the particular part most needed at a time when the tractor is worth a good many dollars an hour to you.

LUBRICATION

MOTOR LUBRICATION

Q. What grade of lubricating oil should be used for a slow-speed tractor motor; for a high-speed type?

A. Every responsible tractor manufacturer goes to considerable expense to determine just what grade of lubricating oil is best adapted to his own engines. His investigation covers everything from a chemical analysis and flash test of every grade of oil recommended for his use to actual tests in service extending over considerable periods of time. The tractor owner should

accordingly never use anything but the oil recommended by the manufacturer.

Q. In a motor having any form of splash lubrication, that is, one in which part of the supply is carried in the crankcase pan, how often should the oil be drained from the crankcase?

A. The recommendations of different tractor manufacturers range all the way from every day to once in two weeks, many giving one week as the maximum period of time the same oil should be used.

Q. How often should the oil in a circulating system be completely replaced with a fresh supply?

A. It should be replaced at the intervals given above for a splash system since the service demanded of the lubricant is the same.

Q. Does oil lose its lubricating qualities through use, and how can this be determined?

A. High temperature and pressure completely change the character of lubricating oil and destroy its lubricating qualities. The lubricating quality of an oil depends upon its viscosity, that is, its *body,* upon which depends its ability to hold apart surfaces under pressure by a film of lubricant. Dip the finger ends in some old oil from the crankcase and rub together under pressure. The oil will have a thin watery feeling and the finger tips may be pressed into close contact through it. Try the same experiment with some fresh oil, and it will be noted that a sliding film is formed between the fingers despite the greatest pressure that can be put upon them to squeeze it out.

Q. What influence has the effect of high temperature and pressure on the length of time during which the oil should be allowed to remain in the crankcase?

A. Both the temperature and the pressure conditions differ widely in different engines so that in some the oil literally *wears out* much faster than in others and should accordingly be replaced oftener. The tractor manufacturer has learned from experience the proper period of time for his motors, and his recommendation is based on a desire to avoid having his customer pay for the same experience.

Q. Next to labor and fuel, lubricating oil is the most expensive item of tractor maintenance. Is it really economy to

replace what appears to be good oil as often as the tractor manufacturer recommends it?

A. The cost of repairs due to a single breakdown from failure of the lubrication would usually buy anywhere from one to five or more 50-gallon barrels of oil, without taking into account the loss of time due to the tractor being out of service. It is the highest form of economy to follow the maker's instructions in this respect; if these are to discard the oil at the end of every day's service, it will be found far cheaper in the end to do so. Many tractor owners do not regard it as necessary to clean out the crankcase more than once or twice a season, but instead of saving oil they are simply running up repair bills.

Q. What other causes tend to destroy the lubricating quality of the oil?

A. Another cause is leakage of the fuel past the pistons so that the supply of oil in the crankcase is thinned out by the gasoline or kerosene. This is particularly true of kerosene, especially if the motor be run at a low temperature so that the kerosene vapor condenses into a liquid. The admixture of carbon and dirt with the oil also tends to destroy its lubricating quality. Compare the color of oil that has been used for some time with fresh oil; the difference is due entirely to the foreign matter that has become mixed with it.

Q. What attention does a force-feed lubricator require?

A. The sight feeds should be watched frequently to note whether oil is constantly passing through them or not. To make certain of this, dirt should be wiped from the glasses at least once a day. While this type of lubrication has the great advantage of constantly feeding fresh oil to the bearings almost as fast as it is consumed, its factor of safety is not so high as that of the splash or circulating type. In other words, failure of the part is apt to follow immediately upon a stopping of the feed since it usually receives no lubrication from any other source. The lubricator must accordingly be watched closely and the engine stopped at once if any of the feeds has become clogged.

Q. How often should such a lubricator be supplied with fresh oil?

A. The maker's instructions may be followed but a still better practice is to get into the habit of keeping the lubricator

constantly filled; that is, of filling it twice or oftener a day, if necessary, rather than waiting until the supply runs low. A gage glass on the side of the lubricator shows the amount in it. The plunger pumps which force the oil to the bearings will always work better when there is an ample supply.

Q. What other precautions should be taken with a force-feed lubricator?

A. When it is driven by a belt, close watch should be kept on the belt to see that it does not become too loose, since any slackening of the belt slows down the pumps and supplies less oil to the bearings.

Q. How often should a force-feed lubricator be cleaned out?

A. Two or three times a season should ordinarily be ample, but this will depend to some extent upon the care that is exercised in handling the supply of oil itself. Unless the oil supply is kept in a covered oil tank, more or less dust and other foreign matter is bound to find its way into it. The presence of dirt in the oil will make itself apparent by clouding the inside of the sight-feed glasses, making them difficult to read. Oil having visible foreign matter, such as small specks of grit, short ends of straw, or chaff, in it should never be put into the lubricator without straining, as it is liable to clog the pump valves.

Q. How is a force-feed lubricator cleaned out?

A. By disconnecting the leads and flushing it out thoroughly with gasoline or kerosene. The leads should be disconnected at both ends and also flushed out, blowing through them to see that they are clear from end to end.

Q. Are some of these leads more apt to clog up than others?

A. Those that supply oil to the pistons are most likely to clog owing to an accumulation of carbon in the ends opening into the cylinder. They should be taken off at shorter intervals and all carbon removed in the tube itself as well as in the opening through which the oil passes through the cylinder wall.

Q. What attention does a circulating system require?

A. A circulating system requires replenishing of the entire supply after washing out at intervals, as directed in the manufacturer's instructions; examination at short intervals of the oil pump; and frequent washing off of the oil pump screen. Keep

the sight-feed glasses clean and shut down immediately if an oil stream fails to appear in any of them (some tractors have but one, others several).

Q. What general precautions should be observed in cleaning out a lubricating system of any type and in handling oil?

A. Always avoid the use of waste or rags from which lint will detach itself in wiping out the crankcase or any part of the system, since these threads will invariably clog an oil pump or feeder tubes. All cans or other vessels used in handling oil should be kept covered to prevent dust falling in them and should be wiped clean before using. Dust is simply fine grit, and its presence in the oil converts it into a grinding compound which will quickly cut away bearing surfaces.

Q. What other lubrication does the motor require?

A. This will depend entirely on the type of motor. Where it has overhead valves as used on many tractor motors, the rocker arm spindles and pin should be oiled at least once or twice a day with a hand oiler. This applies as well to any other external moving parts not lubricated by the oiling system of the motor. The grease cups on the fan and on the pump should be turned down at least once a day. Some tractors are equipped with gravity oilers for this purpose.

CONTROL SYSTEM LUBRICATION

Q. How is the clutch lubricated?

A. On some tractors it is enclosed in the same housing as the motor and runs in a bath of oil. Where it is not housed in, grease cups are usually provided on the clutch, and these should be turned down at least once a day. No oil should be allowed to fall on the facing, as this would reduce the holding power of the clutch and cause it to slip.

Q. What attention is required to keep the transmission properly lubricated?

A. When the transmission is of the enclosed type, running in oil, it should be kept filled to the height given in the maker's instructions and with the grade of lubricant recommended. Don't attempt to use cup grease, or a home-made compound of grease and oil or graphite, as the different materials will separate, nor

should heavy steam cylinder oil be used, since it contains animal fats and will become acid, attacking the steel faces of the gears. The pressure between the gear teeth in a transmission is very high so that the oil *wears out* in time and should be replaced at intervals of two to three months. Watch the transmission housing for leaks and renew felt washers or other provision for preventing leaks.

Q. How are open transmission gears lubricated?

A. Where gears are run without a housing, they are not intended to be lubricated and care should be taken to see that no oil or grease gets on them as it will hold dirt and grit and cause the teeth to wear out much faster. The gears should be kept free of mud and dirt, but an oily rag or waste should never be used for this purpose. This also applies to the bull pinion and gear except where completely housed in.

Q. What attention is required to lubricate other moving parts of the tractor?

A. Grease cups are usually provided on all other moving parts, and they should be turned down as instructed by the maker. In some instances the directions are to screw these cups down as often as twice a day; in others, once an hour.

ENGINE PARTS

ENGINE BEARINGS

Q. How long will motor bearings run without developing sufficient play to require adjustment?

A. This will depend largely upon the motor itself and the service demanded of the tractor. If it is being run constantly with an overload, they will need attention much sooner than when the machine is not called upon to carry more than 75 per cent of its load for the greater part of the time. In any case the bearings should be examined at least once a week; some makers recommend that they be tested for looseness as often as twice a week when in constant service.

Q. How can the bearings be tested for looseness?

A. They should always be examined just after the motor has been shut down and is still hot; the amount of play will be

greater when all the parts are cold but some of this will be taken up by the thickened oil film then present and their condition cannot be determined as satisfactorily. The connecting-rod bearings are the first to show signs of looseness. Take the handhole covers off the crankcase and turn the motor until two of the connecting-rod ends are close to the openings. If there is much play, it will be evident upon grasping the connecting rod and attempting to lift it, but this amount would usually cause a knock in operation. Take a small bar and pry the bearing upward from below, keeping the other hand on the rod to detect any movement. Do not confuse the side play of the bearing with looseness of the bearing itself as a small amount of side movement is allowed on all connecting-rod bearings. Apply this test to the other two connecting rods also. A bar may also be used to detect any looseness of the main or crankshaft bearings.

Q. Will it do any harm to allow a certain amount of play in these bearings?

A. Nothing will be apt to run up a big repair bill quicker than running the motor with the bearings too loose. Every reversal of movement pounds the crankshaft and in time will cause crystallization of the steel with consequent breakage of the shaft. The resulting vibration is also detrimental to every other part of the motor.

Q. How are the bearings adjusted when a test reveals play in them?

A. Most motor bearings are provided with shims, that is, small strips of metal placed between the halves of the bearing and through which the bolts pass to hold the bearing together. Take off one or more shims on each side of the bearing and screw down the nuts again tightly. To obtain a proper adjustment, you must be able to set up these nuts as far as they will go without binding the shaft. Open the pet cocks or the compression release, where one is provided on the engine, and try the adjustment by cranking the motor by hand. It will be very difficult to turn the motor over if the bearings are too tight. They should be adjusted so that the motor turns easily, indicating that there is sufficient space between the bearing halves and the shaft to permit the formation of an oil film between

them. The shaft should be tested for play, as already described, to prevent making the adjustment too loose.

Q. When a bearing is too tight, is it good practice to ease off the nuts and let the shaft run that way?

A. A bearing is not properly adjusted unless the nuts can be set up hard on the bearing caps, all adjustments being made by removing or re-inserting shims, or laminations of metal only a few thousandths of an inch thick. One or two shims should be removed from each side at a time and the adjustment tested. Care must always be taken to see that the bearing cap is replaced on the bearing from which it was taken and that it is *put back in the same way.*

Q. Is it ever necessary to adjust the piston-pin, or wrist-pin, bearing?

A. This is the bearing which holds the upper end of the connecting rod in the piston and if the motor is properly lubricated with clean oil, it will seldom require any attention. In some motors the pin is held fast in the sides of the piston and the connecting rod moves on it, and shims are provided on the connecting-rod bearing for adjustment. In others the upper end of the connecting rod is clamped fast to the pin, and the pin moves in bronze bushings in the sides of the piston or bears directly on the piston walls. Allowing the big-end connecting-rod bearings and the crankshaft bearings to become too loose so that the motor knocks is the chief cause of lost motion in the wrist-pin bearing. Where the pin bears in the piston walls this may wear the holes out of round so that they have to be rebored and bushed to make a good bearing.

Q. When the connecting rod or crankshaft bearings of a motor require adjustment at frequent intervals, what is the cause of the trouble?

A. The cause is faulty lubrication: failure to clean out the crankcase at the proper intervals, with the result that the oil loses its lubricating qualities and the dirt that becomes mixed with it cuts away the bearing surfaces.

Q. Where bearings have become worn to the point where it is no longer possible to adjust them properly, is it practical for the average operator of a tractor to replace them with new bearings?

A. It is not practical unless he has had experience in the work, since it requires accurate lining up and scraping in of the bearings to a close fit. Unless this is carried out properly, such heavy stresses will be imposed on the crankshaft that it will break sooner or later. Therefore it is poor economy to attempt this repair without actually having had experience in making it; it is one of those things that cannot be learned from an instruction book. It is necessary to see it done in the shop more than once and the first attempt should be made under the supervision of one who has had experience.

VALVES

Q. What attention is required to keep the valves in good operating condition?

A. The valve stems must be lubricated one or more times a day, except on motors provided with special means for doing this automatically. The clearance between the valve tappet and push rod, or between the end of the rocker arm and the valve stem, depending upon the type of motor, must be adjusted at frequent intervals and the valves themselves must be ground as often as is necessary to keep them tight.

Q. Why is adjustment of the clearance necessary, and what should this be?

A. The constant hammering of the tappet or rocker arm against the valve stem tends to increase this clearance as well as to wear away the parts, thus increasing the distance. The greater this distance is the less the valve will lift when operated, so that less fuel is admitted on the intake stroke and some of the exhaust gases are left in the cylinder on the exhaust stroke, thus cutting down the power. This clearance should be just sufficient to allow the valve to close completely under the pull of its spring when the tappet or rocker arm is released by the cam. It should be tested and adjusted with the motor hot, since, if made very close when cold, the expansion of the parts is apt to prevent the valve from closing properly. An ordinary visiting card or a piece of tin plate makes a good gage; it should be possible to slip this between the tappet and stem easily. In any case the clearance should not exceed $\frac{1}{32}$ inch.

Q. How often should the valves be ground?

A. When a tractor is being used ten hours a day and six days a week, they will doubtless require grinding once every four to six weeks, depending more or less on the motor itself; some motors run very much hotter than others and in some the provision for cooling the exhaust valve is inadequate, so that more frequent attention is necessary.

Q. How may the valves be tested for leakage without taking the motor down?

A. Turn the motor over by hand about one-third of a revolution, until two of the pistons are within an inch or two of the upper dead center. At this point the pressure in the cylinder that is then on the compression stroke should be highest. Hold the piston up against this pressure, just exerting sufficient pull to cause the piston to move if the compression leaks away. In a motor that is in good condition, there should be no perceptible movement due to leakage in the course of two or three minutes, and if the pull of the hand is slackened, the piston should tend to push the starting crank down again under the influence of the pressure in the cylinder. Apply the test to each cylinder in turn and any difference in the compression-holding power of the different cylinders will be noticeable.

Q. When the usual adjustment of the clearance does not correct a loose and noisy valve action, what is apt to be the cause of the trouble?

A. The pin of the cam roller has probably worn so that there is considerable lost motion between the roller and the pin on which it turns. The only remedy is to replace the roller and pin or maybe the tappet complete. Any lost motion at this point permits the roller to move upward the distance represented by the wear before the tappet itself can lift. While the play at any one point may be very small, when it is increased by an equivalent amount at two or three other points, the total is sufficient to reduce the effective valve opening considerably, with a corresponding decrease in the power. When new parts are not readily obtainable, this condition may be remedied by boring out the holes of the cam roller and the rocker lever and fitting them with bushings.

Q. When grinding valves, is it necessary to continue the operation until the entire valve and seat have taken on a polish?

A. No; the operation may be considered complete when both the valve and the seat are smooth all around and completely free from any sign of pitting. A polished surface may give a little closer fit, but the difference is not enough to compensate for the time necessary to produce it. The grinding operation should always be finished by the use of the fine grinding compound.

Q. In case a motor has been allowed to run until the valve seats have become very badly pitted, is it necessary to cut these down by grinding alone?

A. No; a valve-seat reaming tool should be employed for cutting away the metal until the pitting has almost disappeared, and the remainder of the operation should then be carried out by grinding in the usual manner. No more metal than necessary should be removed with the reamer as cutting too deep will simply shorten the life of the cylinder casting. Valves are made in two standard tapers, 45 degrees and 60 degrees, and care must be taken to see that the angle of the reamer blades corresponds to that of the valve seat before beginning to cut.

Q. Is there any way of testing the tightness of the valves before putting them back into the motor?

A. When the valves are in cages, they may be tested by pouring some gasoline into the cage and noting whether it leaks past the valve or not.

Q. Does a rapid loss of compression under such a test always definitely indicate that the valves are at fault?

A. No; the piston rings may be worn or the lubrication may be poor, so that there is not a good compression seal in the cylinder. To definitely ascertain the trouble, take out the spark plugs and pour an ounce or two of heavy cylinder oil into each cylinder. Turn the motor over fifteen to twenty times with the plugs out to work this oil down on the pistons, replace the spark plugs and repeat the test as first described. Failure to hold compression will then mean poorly seating valves almost invariably, since, with a fresh oil seal, even loose piston rings will hold compression when the motor is being turned over by

hand. The necessity for putting in this oil indicates that the oil in the crankcase or the circulating system needs renewing. This test for loss of compression should be carried out with the motor cold.

Q. What is the best method of grinding the valves?

A. With a valve-in-head type of motor, take the valve cages over to the bench so that there is no risk of getting any of the grinding compound into the cylinders. Use nothing but the specially prepared grinding compound designed for this purpose; ordinary emery and oil should never be employed as it will score the valve and its seat. When a special valve grinder is not at hand, a screw driver bit in an ordinary brace makes the best grinding tool. Smear some of the compound on the valve, drop it on its seat and turn it first one way and then the other, making about a quarter turn in each direction without exerting much pressure. When the compound has been squeezed out, put in more and continue the operation, repeating this for fifteen to twenty minutes. Wash the valve and seat off with kerosene and examine to see if all signs of pitting have been removed and the valve has a bright uniform band around its entire circumference. The presence of any breaks in this ring indicates low spots and calls for further grinding. Never turn the valve completely around when grinding, making only a quarter turn, since the complete turn will score the seat. Be careful to flush off every trace of the grinding compound with kerosene when through to prevent any trace of it getting into the cylinder. Otherwise, the engine will be ruined. Where the valves cannot be taken away from the motor for grinding, the greatest care must be exercised to prevent any of the compound from getting into the cylinders or down into the valve guides.

Q. Why is it necessary to grind the valves at such short intervals?

A. The exhaust valves in particular are subjected to exceedingly high temperatures that pit the metal face of the valve. Once this pitting starts, it proceeds rapidly and if the valves are allowed to run too long without grinding, these pits in the valve face will be so deep that new valves will be necessary. They will also be deep in the valve seat with the result that a correspond-

ingly longer time is required to grind them out. By grinding at the proper intervals, only fifteen to twenty minutes will be required for each valve, whereas if they are allowed to run too long, it may take an hour or more to get each valve and its seat into proper condition again. The motor will also run very much better and deliver more power if the valves are kept in good condition.

Q. What is the cause of a valve leaking very badly at times?

A. Hard particles of carbon from the cylinder may lodge in the pitted face of the seat or valve and prevent if from closing tightly. Even though the valve be held off its seat only a few thousandths of an inch, it cannot hold any compression.

Q. What is the cause of a valve binding so that it will not operate?

A. Worn valve guides will sometimes permit sufficient side play to cause the valve stem to become bent. Lack of lubrication and an accumulation of dirt and carbon in the valve guide will cause the valve stem to expand to a point where it binds hard and fast in the guide.

Q. What causes a valve head to warp so that the valve must be replaced?

A. It may be caused by overheating of the motor due to partial failure of the cooling system, such as may be caused by a slipping fan belt, trouble with the circulating pump, shortage of water in the system, or the clogging of some of the pipes or the radiator. An accumulation of sediment or scale in the jackets or the radiator may have the same effect.

Q. Do valve springs ever need replacement?

A. In the course of a season's use, the temper may be drawn sufficiently to make the valve action sluggish, particularly in a motor that runs very hot, but ordinarily the valve springs do not often need replacement.

Q. Is it ever necessary to check the valve timing of the engine?

A. It is never necessary except in reassembling the engine after it has been taken down. Since the camshafts are made with the cams integral, no relative movement of the cams is possible

and it is only necessary to time one cylinder. Most engines have reference points by which the valve timing may be checked when reassembling the engine.

PISTONS

Q. What attention do the pistons require?

A. The piston rings will wear to such a degree that the pistons no longer hold the compression and there is a substantial falling off in the power.

Q. How often should it be necessary to replace the piston rings?

A. This will depend entirely upon the care that is taken to keep dirt out of the lubricating oil and to prevent its entrance to the motor through the carburetor. If the oil is handled carelessly, containers being allowed to stand uncovered and a film of dust settling on them, or if the carburetor is not provided with an air cleaner, a great deal of grit will find its way into the motor and will grind the piston rings down rapidly and also the bearings.

Q. How may the pistons be tested for tightness?

A. The valves being in good condition, preferably recently ground, the test may be made as previously described for testing the valves; or, with the handhole plates off the crankcase, have an assistant turn the motor over slowly and note whether there is any sound of air blowing down past the pistons into the crankcase. Put a few ounces of fresh oil into each cylinder through the spark plug openings, replace the plugs, and repeat the test. Loss of compression may be due entirely to poor lubrication. Drain the crankcase, wash out with kerosene, and replenish the oil supply; and test in the same manner.

Q. Is wear of the piston rings the only cause for loss of compression, aside from pitted valves?

A. An accumulation of carbon under the piston rings may be holding the piston ring joints apart or the latter may have all worked into line so that the pressure is escaping through them. If, with good tight valves, there is still a loss of compression after putting fresh oil into the cylinders, it is an indication that the piston rings need attention.

Q. Does the compression fail in all the cylinders equally, or is one of the cylinders likely to be worse than the rest?

A. The wear is likely to be uneven, so that one or two of the cylinders will be found very much worse than the rest. Sometimes only one cylinder will fail to hold compression. Test in the same manner as described for the valves, pulling the crank up very slowly to note the resistance offered by each piston in turn as it comes up on the compression stroke. It may be found much easier to move one of the pistons than the others. When this is the case, it will be necessary to fit new rings on that piston.

Q. How are new piston rings fitted?

A. Oversize piston rings are supplied for this purpose. They are slightly larger (a few thousandths of an inch) than those originally supplied with the motor in order to compensate for the wear of the cylinder. Take the old rings off by inserting thin strips of steel (old table-knife blades or discarded hack saws are excellent for the purpose) at three or four points around the piston and under the ring. Scrape and wash out all carbon and gummed oil in the slots. Do not use a file for this purpose. First try the new rings by fitting them in the cylinder, which operation will show how much will have to be taken off to allow them to enter the bore. They must be small enough to insert an inch or two into the cylinder, since it is turned somewhat larger for a short distance at the end. If the rings are too large, take a few cuts with a fine file across the faces of the joint, being careful to keep the surfaces square and parallel. Very little must be taken off each time and the ring tried in the cylinder again. The job must be carried out with painstaking care as unless it is properly done the new rings will be no better than the old ones. When they have been properly fitted, use the same strips to place them on the piston, care being taken not to spring the rings out of round in putting them on.

Q. When fitting rings in the cylinder as a preliminary to putting them on the piston, should the break come together for a good fit?

A. No; allowance must be made for the lengthwise expansion of the ring due to the high temperature, and this allowance must be greater for the top ring than for the lower ones as it becomes hotter. Depending upon the diameter of the cylinder, it is customary to allow $\frac{20}{1000}$ to $\frac{30}{1000}$ inch between the ends of the

topmost ring and $\frac{10}{1000}$ to $\frac{15}{1000}$ inch for the other two. Bearing shims are often stamped with the thickness in thousandths of an inch and may be used as a gage. Unless this allowance is made, the expansion of the ring will cause it to bind against the cylinder wall and may cause scoring.

Q. Must the piston ring be a tight fit in the piston slot?

A. Allowance for expansion must also be made here. After scraping the piston slots free of carbon and washing them out with kerosene so that they are perfectly clean, insert the ring and see that it turns freely in the slot. A piece of coated catalog paper has a thickness of $\frac{4}{1000}$ to $\frac{5}{1000}$ inch and it should be possible to insert a piece of this paper between the ring and the slot. If the rings are too tight they will bind on the piston and cause damage as mentioned above. Unless they can be moved freely in the slots, they will have to be made smaller by taking metal off the bottom edge of the ring. Smear some valve grinding compound on a flat metal plate or a smooth piece of hardwood plank and rotate the ring in this under pressure with the hand. Be sure to wash off all traces of the grinding compound before trying on the piston again.

Q. Do the pistons themselves ever have to be replaced?

A. The same condition that causes rapid wear of the piston rings, that is, dirt in the lubricating oil, will also cause equally rapid wear of the pistons. When this wear amounts to $\frac{15}{1000}$ to $\frac{20}{1000}$ inch, the piston will rock on the piston pin in the cylinder and produce a distinctive noise, known as *piston slap*, which cannot be traced to any other cause. At first, it is likely to be attributed to a loose bearing, and as it increases it will greatly resemble a bearing knock. When one piston reaches this stage, it is better to replace all of them with oversize pistons. The cylinders should be examined carefully for scoring and tested to see if they have worn out of round as it may be necessary to rebore them or to replace the cylinder casting to make a good job of it.

Q. Can the pistons be tested for looseness without taking the motor down when a knock cannot be traced to any other cause?

A. The amount of wear that will cause considerable piston slapping is so small that it would be difficult to detect it without

having the cylinder and piston on a bench where the fit can be examined closely. The average driver would never attribute the loud knocking caused by a loose piston to the apparently slight amount of play that is revealed when the piston is examined.

Q. What causes besides dirt in the lubricating oil will bring about rapid wear of the pistons or scoring of the cylinders?

A. Other causes are the use of a poor grade of oil, using the same oil too long, or any other condition that results in inefficient lubrication, such as overheating due to partial failure of the cooling system. Unless there is a good oil film between the piston and the cylinder, the metal comes into actual contact and scoring follows. Too thin an oil will be burned away by the heat of the explosion as fast as the film is formed on the cylinder, while too heavy an oil may not reach the upper end of the cylinder bore owing to failure to pass the piston rings. Worn piston rings will permit particles of carbon from the combustion chamber to work between the piston and the cylinder wall. Partial failure of the lubrication system, such as the clogging of an oil lead in a force-feed system, the clogging of the screen or of the pump in a circulating system, or an insufficient supply of oil in a splash system, will result in scoring.

Cylinder scoring may be due to the piston ring binding owing to failure to allow for expansion in fitting or to the piston sticking owing to an accumulation of carbon under it. The wrist pin may become loose and move endways so that it scrapes against the cylinder wall; or in assembling the piston and connecting rod, the wrist pin may be so placed that it presses the piston unevenly against one side of the cylinder. Carelessness in valve grinding that results in some of the compound getting into the cylinder will cause serious scoring sooner than almost anything else.

CARBURETOR

Q. What attention does the carburetor need?

A. It should be drained at frequent intervals to remove the accumulation of sediment. Care should be taken to prevent dirt from getting into the fuel, and the latter should be strained as it is poured into the tank. In making needle-valve adjustments, the needle must never be screwed down hard on its seat, since this is

likely to turn a shoulder on it so that proper adjustments cannot be made with it.

Q. When the carburetor floods, what is the usual cause of the trouble?

A. The usual cause is dirt lodging under the needle valve in the float chamber. Where a hollow copper float is used, it may have sprung a leak, causing it to sink.

Q. How should the carburetor be adjusted to give the maximum power with the most economical fuel consumption?

A. Definite instructions covering every make of carburetor cannot be given, but the same principles can be applied to all. With the motor running, cut down the fuel supply gradually until the motor begins to run irregularly or to miss. The fuel mixture is thus made leaner, and in some cases the motor will back fire through the carburetor when the mixture becomes too lean. When the point of adjustment has been found at which the motor is not getting sufficient fuel, turn back slightly until just enough fuel is being supplied to permit it to idle regularly. This is termed the low-speed adjustment and some carburetors have no other, that is, only the fuel supply can be regulated. Others have a high-speed adjustment as well; this controls the air supply and takes the form of an adjustable auxiliary air valve. Speed the motor up and release the tension of the auxiliary air valve spring until the point is reached where too much air is being admitted and the mixture again becomes too lean. Then turn back slowly until as much air is being admitted as is possible without causing irregular operation.

Q. Does the working of any other part of the motor influence the carburetor adjustment?

A. Unless all other parts of the motor are in good working condition, it will be found impossible to make a satisfactory carburetor adjustment. Valves in need of grinding, excessive clearance between valve tappets and stems or rocker arms, worn piston rings or pistons, and worn valve guides will all influence the adjustment of the carburetor. Air drawn in through worn valve guides, a leaky intake manifold, or a leak at the throttle valve of the carburetor will weaken the mixture and make it too lean, so that the motor loses power and overheats. With the motor running,

take a squirt can and put some gasoline on the intake manifold gaskets and around the valve stems and note whether it is drawn in or not. New gaskets will remedy trouble of this nature at the manifold. Whenever the manifold has to be taken down, it is always better to replace the gaskets, since it is difficult to make used gaskets tight.

Q. The float valve and needle adjustment being in good condition, what is the cause of the trouble when a regular flow of fuel cannot be obtained at the nozzle in the mixing chamber?

A. The supply line may be partially clogged or the vent hole in the top of the carburetor may be stopped up. This is a small opening designed to admit air in order that there may be atmospheric pressure on the fuel in the float chamber. If this clogs up, a partial vacuum is formed. In a gravity system the air vent on the tank may have become stopped up and the fuel will not flow to the carburetor owing to the lack of atmospheric pressure on top of the supply. In a pressure or a vacuum tank supply system the trouble may be with the pump, or with loose joints, or with the tank itself.

Q. When difficulty is experienced in making a satisfactory low-speed adjustment, what is likely to be the cause?

A. The needle valve may have been forced down on its seat so that a burr or ring has been formed on the needle. The latter should be taken out and repointed.

Q. Is an air cleaner indispensable in connection with a tractor carburetor?

A. It will save its cost and the time required to attend to it many times over. Without it, pistons, rings, and bearings will grind out very rapidly, and trouble will be experienced with accumulations of carbon, more than half of which will be nothing more nor less than dirt drawn in through the carburetor.

Q. What attention does the air cleaner require?

A. Frequent cleaning is the only attention needed. When the cleaner is of the dry-air type, the engine should always be shut down before emptying it. If it is a washer type, see that it is constantly supplied with plenty of water. Clean out either type twice a day or oftener, if necessary, rather than wait until it is full. Analyses of carbon accumulations taken from automobile

cylinders have shown them to consist of 65 per cent, or more, of road dirt.

Q. How can an over-rich mixture be detected?

A. Note the color of the exhaust from the muffler. The presence of black smoke indicates that too much fuel is being fed; blue smoke, too much lubricating oil; and grayish-white smoke, poor combustion of kerosene usually due to an excess of water. An over-rich mixture, particularly when kerosene is being used, will cut the lubricating oil from the cylinder walls and cause scoring unless remedied.

Q. What is the object of feeding water with the fuel?

A. To assist in keeping the temperature of the engine down to the proper point for satisfactory working. The steam generated rapidly absorbs a great deal of the heat and has the further advantage of preventing the formation of carbon in the cylinders. It also causes better combustion, particularly in the case of kerosene.

Q. Should water be fed with the fuel regardless of the grade of oil employed?

A. Little or no water is necessary when using gasoline, but the majority of motors will not operate satisfactorily on kerosene without it.

Q. Is there any danger of feeding too much water, particularly when the motor is running very hot and appears to need it?

A. Excess water fed with the fuel is liable to lower the temperature to the point at which kerosene recondenses to a liquid; in such a case considerable of it works its way past the pistons and down into the crankcase. This destroys the film of lubricant on the cylinder walls and is liable to cause damage, not alone to the cylinders themselves but likewise to the bearings; thinning the oil in the crankcase destroys its lubricating qualities. If the motor appears to be getting too hot, the trouble should be remedied by locating the fault in the cooling or the lubricating system and not by attempting to overcome it by increasing the amount of water fed.

Q. What indication is there of excessive water in the fuel?

A. A grayish white smoke will appear at the exhaust indicating that the kerosene is not being completely burned in the

cylinders. Cut down the water supply very gradually until the smoke disappears, the motor being kept running at a good speed, since if run too slowly on kerosene the combustion of the latter will not be complete owing to the drop in temperature.

Q. Are all tractor motors provided with hand-controlled apparatus for feeding water?

A. No; some carburetors are designed to feed water automatically as it is needed, while in others the use of a wet air cleaner is depended upon to supply the proper amount of water required.

Q. Where hand control is provided, should the water be fed as long as the engine is running?

A. It is better to shut it off five minutes or so before the motor is to be stopped, and the fuel should be switched from kerosene to gasoline at the same time, as this will leave the motor in better condition and facilitate restarting.

Q. What precautions should be taken with the water supplied for this purpose?

A. Clean rain water should be used, and it is well to strain it through two or three thicknesses of cloth to prevent the entrance of any dirt.

COOLING SYSTEM

Q. When the engine overheats despite the fact that the cooling system is working properly, what is the cause of the trouble?

A. It may be due either to an over-rich or an over-lean mixture. In either case combustion is slow instead of taking the form of the explosion required to produce the maximum power. The mixture continues to burn throughout the stroke and in the exhaust passages and muffler. Flame issuing from the exhaust is an indication of this condition. The ignition may be retarded too far and bring about the same condition.

Q. What are some of the causes of failure of the cooling system?

A. Among the causes are the following: insufficient water supply; fan belt slipping; pump running too slow when driven by a belt; insufficient lubrication; leaks in radiator or at pump packing permitting water to escape or air to enter; and clogging of radia-

tor, circulating pipes, or water jackets with an accumulation of sediment. The cooling system should be drained at frequent intervals and flushed out with clean water. An accumulation of carbon in the cylinders will also cause the engine to overheat and if allowed to become very bad, will cause preignition, which imposes very heavy stresses on all moving parts of the engine.

Q. When hard water has to be used in the cooling system and scale forms, how can this be removed?

A. A strong soda solution made by adding several pounds of common washing soda to enough boiling water to fill the system should be used for a day or so in place of ordinary water. The system should then be drained and flushed out. The use of rain water will prevent the formation of scale. Particles of iron rust in the water when the system is flushed should not be confused with scale; these will always be found, even if the system is drained every day.

Q. Do the flexible-hose connections ever cause any trouble?

A. The inner plies of the hose sometimes become detached owing to the high temperature of the cooling water and either partially or wholly clog the passage. The passage is liable to become wholly clogged with the pump type of circulation owing to the much smaller diameter of the hose used. To guard against trouble of this nature, use nothing but the hose connections supplied by the manufacturers as replacements since this hose is specially made to withstand hot water. Ordinary hose will disintegrate rapidly when employed for this purpose and should never be so used except to tide over an emergency, being replaced with a new connection as soon as possible.

Q. Is partial or total failure of the cooling system the only cause of overheating?

A. No; there are numerous other causes of overheating. The motor may be run with the ignition retarded; the lubrication may not be efficient; or carbon may have accumulated in the combustion chambers, as pointed out in a previous answer.

Q. How can carbon be prevented from accumulating in the motor?

A. After the motor has been shut down for the day and is very hot, take out the spark plugs, turn the motor over by hand until all the pistons are at approximately the same height, and

pour into each cylinder about an ounce of kerosene, letting it stand this way over night. Do not use more than this amount of kerosene (a tablespoon will hold about an ounce) on the theory that if a little does good, more will do better, since more kerosene will cut the lubricating film off the cylinder walls and thin the oil in the crankcase.

Q. How can the fan belt be kept in good condition?

A. Make adjustments only when the motor is hot and do not put any more tension on the belt than is necessary to prevent slipping. A belt that is set up too tightly will wear very quickly besides imposing undue stresses on the pulley bearings. Keep the leather soft by applying neatsfoot oil from time to time.

Q. How often should the radiator and cooling system be drained?

A. Two or three times a season are sufficient in summer if clean rain water is being used and it is strained before being put into the radiator. In winter it will be found better practice to drain the entire system every night rather than to depend upon an anti-freezing solution, since the latter lowers the boiling point of the water to such an extent that it is likely to boil away. In any case, if alcohol is used in the anti-freezing solution, it is likely to boil out of the water, so that the latter cannot be left in over night with safety. Some tractors are cooled by oil, and in cold weather it is necessary to thin this oil with kerosene before it will circulate freely.

Q. When it is discovered that a considerable quantity of the water has boiled away and the motor is very hot, is it good practice to fill up with cold water immediately?

A. This should not be done, particularly in winter, as the fresh supply is likely to be very cold and the sudden contraction would impose severe stresses on the radiator joints, starting leaks.

Q. What attention does the pump of a circulating system require?

A. See that the glands are kept tight. The appearance of a drop of water at the gland indicates the beginning of a slow leak. Give the gland nut a partial turn to tighten it; if water still appears, it will be necessary to repack the stuffing box. Use oil-soaked cotton wick or graphite packing.

HORSEPOWER RATINGS

Q. Why are tractors rated as 10–20, 16–30, etc., always giving two horsepower ratings?

A. Tractors are designed to be used for belt as well as for field work. In doing the latter, the tractor must use a substantial percentage of its power to move itself. The lower rating accordingly expresses the amount of power available for plowing. When standing, as in performing belt work, the only losses are caused by whatever transmission gearing is interposed between the engine and the belt pulley, so that almost the entire output of the power plant is available for driving other machinery.

Q. What constitutes an overload, and why do all manufacturers warn the tractor user so strongly against subjecting the machine to overloads?

A. Considerable confusion exists as to the meaning of the term horsepower. For a few minutes, as in pulling out of a hole, a heavy draft horse is capable of exerting 600 to 800 pounds drawbar pull, which is the equivalent of more than 1 hp., but the same horse cannot exert much more than an average of 100 pounds drawbar pull at a speed of three miles an hour in hauling a load all day. The fact that a tractor having a field rating of 16 hp. may be pulled out of a bad place by three heavy horses does not indicate that the team is capable of doing as much work as the machine. The animals can only exert this much power for a very short period. The tractor will generate an amount of power at the drawbar equivalent to fourteen or fifteen horses at the usual plowing speed and will keep it up all day. A load such as twelve horses could haul all day would represent the practical working maximum for such a machine. A heavier load than this, apart from emergencies which call for all the power the machine can produce for only a very short period, would represent an overload for that tractor. In other words, the tractor should not be steadily subjected to a load amounting to more than 75 per cent of its capacity. Manufacturers warn tractor owners against overloading their machines because tractors will wear out very quickly under the excessive strain and will not give satisfactory service during the machine's greatly reduced useful life. Regardless of the plow rating of the tractor, as for instance, three-plow or four-

plow, the number of plows used should depend upon the nature of the soil. When the latter is very heavy, or the plowing has to be done on an up grade, fewer plows should be used. More and better work will be done by not subjecting the tractor to any greater load than it can pull without exerting more than 75 per cent of its power.

ENGINE TROUBLES

FAILURE TO START

Q. What are some of the commoner causes of failure to start?

A. Over 95 per cent of all failures to start are due to either lack of fuel or lack of the spark to ignite it. Part of the remaining 5 per cent are due to the failure of the two to come together at the right time, while the rest may be put down to faults having no connection with either the carburetor or the magneto.

Q. Does lack of fuel in this connection mean an empty tank and nothing more?

A. While a great deal of energy has been expended to no good purpose in trying to start an engine that was connected to an empty gasoline tank, lack of fuel implies a great deal more than that. It does not do much good to have a full tank unless the fuel is actually getting into the cylinders every time the engine turns over. There may be a stoppage between the tank and the carburetor or between the latter and the cylinders. A plugged air vent either at the tank or at the carburetor will prevent the liquid fuel from reaching the carburetor nozzle. A stopped-up carburetor nozzle will not vaporize any fuel, while a broken throttle connection which leaves the throttle closed will not permit any spray from an open nozzle to reach the motor, or at least not enough to render starting easy. Air leaks at the carburetor, the manifold, or the valve stems will weaken the mixture considerably.

Q. Is it not as hard to start with too much fuel as with too little?

A. Flooding the cylinders makes starting very difficult, and when this has occurred, the only remedy is to shut off the supply entirely and crank the motor for a few minutes to clean out the

cylinders. Priming too freely is a bad practice, since the liquid gasoline cuts the lubricating oil from the cylinder walls and destroys the compression to such an extent that in an old engine it is next to impossible to start even though the fuel and the spark come together in the right place at the right time. This is one of the unspecified causes responsible for part of the 5 per cent of the failures to start mentioned previously. There will be a weak explosion every time a cylinder should fire, but not enough power will be produced to cause the engine to take up its cycle and run.

Q. When the cylinders have been flooded by over-priming with gasoline, what should be done?

A. Close the throttle and open the air valve or choker, so that no gasoline is drawn through the carburetor. Take out the spark plugs and put 2 or 3 ounces of heavy cylinder oil into each cylinder. Replace the plugs and turn the motor over for two or three minutes with the ignition off.

Q. Has the position of the throttle lever any effect on the fuel supply at starting?

A. Some engines can only be started readily with the throttle at a certain position, usually not more than one-third open and sometimes considerably less. On a cold morning opening the throttle too far is liable to allow too much gasoline in liquid form to find its way into the cylinders, so that the effect is the same as that of over-priming or flooding.

Q. How should an engine be primed?

A. Gasoline should be carried in a squirt can for this purpose and not more than a teaspoonful should be squirted into each cylinder through the pet cocks. If the engine does not start after priming two or three times, look for some other cause of fuel or ignition failure. If the engine starts and only turns over a few times and then stops, the cause is likely to be lack of fuel as indicated by the fact that it ran on what was injected into the cylinders. In priming the float in the carburetor is also depressed by means of a button or lever provided for the purpose. This floods the carburetor and causes the gasoline to overflow through the nozzle into the mixing chamber. The moment any gasoline leaks out of the carburetor, the float should be released, since

otherwise the cylinders will be flooded. Never prime the carburetor just as the engine is starting, as this will produce an over-rich mixture and probably cause a pop back which may ignite the gasoline in the carburetor.

Q. Is water in the gasoline a frequent cause of failure to start?

A. It may not be a very frequent cause, but the occurrence of any water in the gasoline will make it difficult to start the motor. Being heavier than gasoline the water sinks to the bottom of the tank and there may be enough of it to partly fill the carburetor. The remedy is to drain the carburetor, taking out a half-pint or so.

Q. What effect does the use of kerosene as fuel have on the starting of the motor?

A. It has no effect, if the matter is properly handled. At least five minutes before the engine is to be stopped the kerosene should always be shut off and the engine allowed to run on gasoline so that all traces of kerosene will be cleaned out of the cylinders and the manifold. If this has not been done, it will take considerable cranking to start the engine, and it may also be necessary to inject 2 or 3 ounces of fresh oil into each cylinder to renew the compression seal since the kerosene condenses in the cylinders as soon as they get cold and then runs down past the pistons into the crankcase.

Q. Will an adjustment of the mixture make starting any easier?

A. The actual adjustment of the carburetor itself should never be disturbed for starting purposes, as, if this is done, either the carburetor will seldom be properly adjusted for efficient running or a great deal of time will be spent unnecessarily in making adjustments. Moreover the carburetor parts will soon wear badly and make efficient adjustment impossible. Most carburetors are provided with a *choker* which, when closed, causes all the air to be drawn past the nozzle, thus increasing the suction and giving a rich mixture. This should be closed for starting and opened the moment the motor gets under way. Ordinarily the running mixture is too lean to make starting easy.

Q. What are the commoner causes of failure to start through ignition trouble?

A. Among the causes are the following: a ground or short-circuit in the wiring; points of plugs burned too far apart; moisture on the distributor of the magneto; failure of the contact points in the breaker box of the magneto to separate when the cam strikes the hinged lever; impulse starter of magneto stuck or spring broken; putting plug cables on wrong plugs when a change has been made just before attempting to start; badly sooted plugs; spark lever advanced too far; and loose connections, particularly where a separate coil is used with the magneto.

Q. What simple test can be made to determine whether the spark is occurring in each cylinder at the proper time?

A. Take out the plugs, leaving the cables attached to them, and lay the plugs on the cylinder head. Then turn the motor over slowly and note whether or not the sparks occur at the plugs in the proper sequence. Note whether there is a strong blast of air from one of the spark plug holes each time the motor is turned over; if not, pour an ounce or two of fresh oil into each cylinder. The failure to start may be due to lack of compression.

Q. If, when the spark plugs are thus placed, no spark occurs at them, where should the trouble be sought?

A. Take off the cover of the contact breaker of the magneto; have an assistant turn the motor over slowly, and note whether the points of the contact breaker separate twice per revolution (four-cylinder motor). If they do separate, note whether the faces of the contact points are clean and square. If they are blackened or pitted, clean and true them up with a very fine file or a strip of fine sandpaper, and then so adjust them that they come together firmly when the cam is horizontal and do not separate more than $\frac{1}{64}$ inch when the cam is vertical. By giving the motor a sharp turn beyond a compression point a spark will be noted between the points; or the impulse starter may be used and the result noted.

Q. Assuming that a spark takes place between the contact points of the magneto, but none occurs at any of the spark plugs, where should the trouble be sought?

A. Open up the distributor of the magneto and wipe it free of any moisture or dirt that may have accumulated on it. Turn the motor over and note whether the distributor brush revolves as

it should. Adjust all the spark plug gaps to not more than $\frac{1}{32}$ inch; see that the plugs are properly cleaned and that they are lying on their sides on the cylinder heads, so that only their bodies come in contact with the metal. If they are so placed that the central electrodes are touching, the current will pass through them without causing a spark, since there are then no gaps for it to jump. In case none of these tests produces a spark at the plugs, there is more than likely to be some internal trouble with the magneto, though this is of comparatively rare occurrence.

Q. When the impulse starter fails to operate, what is likely to be the cause of the trouble?

A. Either the mechanism has become gummed up with oil and dirt or the spring has broken. Cleaning out the impulse starter with gasoline and re-oiling will remove the former cause.

Q. When the engine fails to start after having been primed once or twice and cranked several times, in what order should the cause of the trouble be sought?

A. This will depend largely upon weather conditions. In very cold weather it is quite likely that nothing but the low temperature is the cause of difficulty in starting. Results will usually follow continued cranking, as this warms the engine up somewhat and makes it turn over easier, with the result that the first weak explosions may cause it to take up its cycle. In warm weather, if a start does not follow several attempts at cranking, test the ignition first and then the fuel supply, applying the different tests already outlined and in about the order given.

Q. Are there any other points in the ignition system that are likely to be responsible for failure to start?

A. If, when turning over, the motor produces a spark at the contact breaker but none at the plugs, investigate the magneto switch. It may have become broken or its connections may be faulty. See that it is in the right position, since many tractor motors can only be stopped by short-circuiting the magneto by means of the switch. In case the switch is in the *STOP* position, no spark will occur at the plugs. On some tractors the spark-advance lever takes the place of the switch; by fully retarding it the magneto is short-circuited, and the motor cannot be started.

Q. Do the magnets of the magneto lose so much of their strength that no current is produced?

A. In time, the heat and vibration are liable to weaken the magneto, but this is far from being a common source of trouble. If, after making the tests mentioned, no spark is produced, take off the distributor plate of the magneto and rest a screwdriver blade on the gear casing so that its end comes within $\frac{1}{8}$ inch of the collector ring. Turn the motor over, and note whether a spark jumps this gap. A $\frac{1}{8}$-inch spark at this point will indicate that there is no falling off in the power of the magneto. If a spark cannot be produced in this way, there is something wrong with the magneto itself, and it should be sent to the manufacturer for repairs. Ordinarily remagnetization is only necessary if the magneto has been taken apart and the magnets allowed to stand without a "keeper," or piece of soft iron across their ends, or if they have been removed from the magneto and reassembled in the wrong way.

Q. When the contact points have become so badly pitted and burned away that they cannot be properly adjusted after cleaning and trueing up, what should be done?

A. One or both of the contacts should be replaced and adjusted properly. The magneto manufacturer usually supplies a special wrench for this purpose, one end of it serving as a gage for the proper gap between them. The lock nut of the movable point should always be screwed down firmly after the adjustment has been made or it will back off owing to the vibration.

Q. Are there any connections on the magneto which are likely to become short-circuited or grounded?

A. When the wire is brought out through the side of the magneto, the insulation may become so worn that the metal touches the side of the opening, causing a short-circuit. In the inductor types of magneto, such as the Remy and K–W, this is most likely to occur at the grounding screw where the wire is fastened to the side of the magneto. In shuttle-wound types, such as the Eisemann, Kingston, and Bosch, the break may be at the point where the wire is fastened to the armature or where it is fastened to the collector ring.

Q. Can the contact breaker become short-circuited?

A. Metallic dust or filings will be liable to cause this; the remedy is to clean out the inside of the box with gasoline. Whenever an adjustment is made, the contact points must always be redressed so as to come together squarely. For this purpose use only the small file supplied by the manufacturer, and take off just as little of the platinum as possible, since it is worth considerably more than gold.

Q. How can the contact-breaker box be tested for a short-circuit?

A. Remove it from the magneto, place a piece of paper between the points, and then hold the box within $\frac{1}{8}$ inch of the shaft while the magneto is turned over with the other hand. No spark should occur; if it does, it indicates that the insulation of the adjustable contact point is poor and should be replaced. The test should then be repeated with the paper removed so that the points are in contact; a spark should then occur when the armature is turned over, the breaker box being held within $\frac{1}{8}$ inch or less.

Q. Does oil getting on the parts injure the magneto in any way?

A. If allowed to get between the contact points in the breaker box, it will insulate them. On the shuttle-wound types of magneto there is a collector ring and brush, and allowing any oil to get on them will prevent the operation of the magneto altogether. Oil usually carries more or less dirt with it, and if allowed to get on the distributor, it is liable to cause leakage of the high-tension current, so that no spark occurs at the plugs.

Q. How often should the contact points of the magneto need attention?

A. This will depend more or less on the particular type of magneto and the engine, but they should be inspected at least once every thirty days while the tractor is in service steadily and trued up with the sandpaper or special file whenever the slightest irregularity of their surfaces is evident. Taking off a little at frequent intervals will keep the points in much better condition and will save the costly platinum, since once the points start to pit this process proceeds very rapidly. Emery should never be used on the points.

Q. Is excess oil in the motor ever a cause of failure to start?

A. When there is so much oil in the motor that considerable of it finds its way into the combustion chambers, it will collect on the spark plug points and insulate them, if unburned, or short-circuit them, if carbonized. The fact that the motor apparently ran satisfactorily just before being shut down the last time is not conclusive evidence that the spark plugs are in good condition. The magneto generates a high voltage when running at full speed, and the motor will often continue to operate in spite of poor conditions whereas it cannot be started again, once it has become cold, without first remedying the faults.

Q. What is the commonest cause of failure to start a motor equipped with low-tension ignition?

A. Dirty plugs, or ignitors, are probably the most frequent cause. As in the case of the high-tension spark plugs just mentioned, the engine may continue to run with the plugs in poor condition, but once it has been shut down and allowed to become cold, the magneto will not produce a spark at the dirty plugs at the low speed at which the engine is cranked. Whenever an engine with this type of ignition is difficult to start, the first thing to do is to examine the plugs. Give them a thorough cleaning with gasoline and a wire brush, taking out the moving contact to remove any soot that has been forced into the bearing. These plugs may be tested by laying on the cylinder head, contacts up, and snapping the contact with a small piece of wood while an assistant turns the motor over so that the magneto is generating.

Q. What other attention do these plugs require?

A. The contact points burn away rapidly and need frequent dressing up to keep their contact faces from becoming pitted. They should be trued up in the same manner as directed for the magneto breaker-box contact points, and while the material is not so expensive, no more than necessary should be taken off. The operation should be repeated at frequent intervals to keep the plugs in good condition.

Q. How may the low-tension magneto be tested to find out whether it is generating or not?

A. Place a screwdriver blade against the single terminal of the magneto and hold the end against some metal part of the

motor while the motor is cranked. Move the tip of the screw-driver over the metal while maintaining contact with the terminal at the other end and sparks will be noted at the tip. A similar test may be made by disconnecting the cable leading from the coil. Rub the metal terminal of this cable over different adjacent parts of the motor so that contact is made and broken while the engine is being cranked, and much larger sparks will be noted.

Q. If, after making tests successfully, no spark is obtainable at the ignitor plug itself, what is the cause of the trouble?

A. The plug is likely to be at fault. Oil that has been used for any time carries in solution a considerable percentage of carbon in a finely divided state. When hot, this oil is thin and is forced into the insulation of the plug, short-circuiting it, though apparently there is nothing wrong with it. The only remedy is to renew the insulation of the plug.

Q. Though a test of the ignitors shows them to be in good working condition, the motor still fails to start and examination shows every other part to be working properly, so that the fault is evidently with the ignition, what is the cause?

A. Either some part of the ignitor tripping mechanism has failed, so that the contacts do not separate, or the timing has become deranged, so that the separation takes place at the wrong moment. In the latter case the spark is occurring in the cylinder, but it is taking place either too soon or too late to fire the charge. Check up the timing of the ignitor mechanism in accordance with the maker's instruction book.

Q. How can the dry cells ordinarily used for starting with low-tension ignition be tested?

A. A pocket ammeter, or so-called battery tester, should be used for this purpose. Hold the tips on the cells only long enough to allow the instrument needle to come to rest, since the ammeter represents a dead short-circuit on the battery and will run it down very quickly. If the reading of the ammeter shows less than 10 amperes, the batteries are of no further use for starting purposes and should be renewed. Any other method of testing will only show whether the battery is actually dead or not, and dry cells may make a fairly large spark through the coil but will give a reading of only 2 to 3 amperes on the instrument and will fail to

ignite the charge in the cylinder. Batteries when this low give out very quickly. If the switch has been left on the battery side inadvertently, give the cells ten to fifteen minutes to recuperate and then test again.

Q. What is likely to go wrong with the wiring of a low-tension system?

A. About the only thing that can happen to this wiring is a loose connection at the magneto, at the ground on the motor, at the ignitor connection, or at the switch. The switch itself may become short-circuited and thus prevent any current from reaching the plugs.

Q. Does the tripping mechanism of a low-tension system require frequent attention?

A. The trip-rod mechanism should be inspected from time to time to see that it is working normally, as the vibration is likely to knock it out of adjustment. The springs should be replaced whenever they show any signs of weakening.

RUNNING TROUBLES

Q. What causes the engine to emit smoke?

A. Among the causes are the following: an over-rich mixture caused by faulty adjustment of the carburetor; and flooding of the carburetor due to a leaking metal float or a water-logged cork float. In either of these cases the smoke will be black. Oil getting into the combustion chambers in excess, caused by feeding too much oil or by broken or stuck piston rings, will produce a blue smoke. Feeding an excessive amount of water when burning kerosene or running the engine too cold will produce a white or gray smoke, indicating that the kerosene is not being entirely consumed.

Q. What is the cause of back firing through the carburetor?

A. A slow-burning fuel mixture is being fed, that is, one either too lean or too rich, usually the former, so that there is still flame in the cylinder when the valve opens. At times this will occur to such an extent that the flame issues from the exhaust pipe at the end of the muffler. This is an indication that the mixture is too rich, since it is still burning after being exhausted from the cylinder. One of the valves may not be closing properly;

it may be held off its seat slightly by an accumulation of carbon, or its stem may have become bent, so that the spring cannot close it. When the ignition has been dismantled, reassembling the cables on the wrong plugs so as to alter the firing order will cause a back fire, but in this case the engine cannot be started. An air trap in the fuel line or partial clogging of the latter will also cause this at times.

Q. What are the commoner causes of missing?

A. The most frequent cause is a defective spark plug. Owing to the heat and the vibration the porcelain of a plug will break, but the cracks will be so small that they are invisible. The pressure forces carbon-laden oil into these cracks and the plug becomes short-circuited, though apparently in good order. Test by short-circuiting the plugs in turn with a wooden-handled screwdriver. When short-circuiting a plug causes no perceptible difference in the running of the engine, replace it. Pitted and badly worn contact points in the magneto breaker box will also cause irregular running. (See the directions given under Failure to Start.) Missing may also be caused by the fuel mixture being too rich or too lean, partial stoppage of the fuel line, water in the gasoline, defective insulation or loose connections, carbon dust on the distributor plate of the magneto, or a sticking valve.

Q. In what other ways may spark plugs fail besides the porcelain cracking?

A. Very frequently the electrodes burn too far apart, so that the current is unable to jump the gap, or if it does, the spark is weak and irregular. Plugs become foul through an accumulation of soot in them, and to clean a badly sooted plug out thoroughly, it may be necessary to take it apart. The insulation of a mica plug will fail in time through the hot oil and carbon being driven into it under pressure, and the only remedy is to replace the insulator. Leakage around the gasket sometimes occurs, and when it is not sufficient to cause a hissing noise, it will be indicated by the porcelain of the plug becoming very dirty. Squirt a little oil on the porcelain when the engine is running and bubbles will form at the gasket if the plug is leaking. Cheap plugs are made with iron electrodes, and the latter burn away so fast that it may be necessary to adjust the gap once a day.

Q. What is the cause of preignition?

A. Usually an accumulation of carbon in the combustion chamber. This carbon deposit often takes the form of small cones which become incandescent when the engine is running under full load so that the fresh mixture is ignited the moment it enters the cylinder. When running on kerosene, the piston head may become so hot as to produce the same result. In either case, preignition will be evidenced by a heavy pounding and the engine should be stopped at once as this imposes a very heavy stress on all the moving parts. Increasing the amount of water fed with the fuel will remedy it when it is due to overheated pistons and the use of kerosene. Otherwise, the engine will have to be cleaned out to remove the carbon.

Q. How can the accumulation of carbon be prevented?

A. By using only the grade of oil recommended by the manufacturer of the tractor; cleaning it out and putting in a fresh supply as often as directed; keeping the piston rings in good condition, so that an excessive amount of oil cannot find its way into the combustion chambers; and keeping the carburetor properly adjusted, so that too rich a mixture is not used. Feed the proper amount of water when burning kerosene. In spite of these precautions, more or less carbon will always accumulate in the cylinders. This amount can be kept down to a minimum by pouring a few ounces of kerosene into each cylinder at the end of a day's run when the engine is still very hot and leaving this in the cylinders over night. Before starting up in the morning, the compression seal should be renewed by putting a few ounces of fresh oil into each cylinder.

Q. When the engine fires regularly but the explosions are so weak that very little power is produced, what is the cause of the trouble?

A. Some of the commoner causes are as follows: spark plug points burned too far apart; excessive clearance at the valve stem tappets or rocker arms, so that only a fraction of the fuel required is being admitted; valves in need of grinding; poor compression caused by oil not being renewed at sufficiently short intervals; broken or stuck piston rings; leaks around spark plugs; use of a fuel mixture that is too lean or too rich, so that slow burning

results instead of an explosion; a weakened or broken valve spring; clogging of the passages of the muffler with carbon; or any obstruction in the exhaust piping.

Q. What causes the engine to run regularly for a time and then to misfire badly?

A. This may be caused by switching to kerosene before the engine has run long enough on gasoline to become thoroughly warmed up; a valve with a bent stem that operates properly at times and then sticks during a few revolutions; air leaks around the valve stems or in the intake manifold; dirt in the carburetor, so that the nozzle is partly clogged at times and free at others; defective insulation or a loose connection which interrupts the circuit from time to time owing to the vibration of the engine, causing it to change position; water in the gasoline; carbon on the distributor plate of the magneto; or faulty spark plugs which will permit the engine to run regularly when idling but which will fail the moment the load is applied. A spark plug with fine cracks in the porcelain will fail under load owing to the greatly increased pressure in the cylinder, but will often spark regularly when the engine is running without load. A loose connection or weak spot in the insulation is the most puzzling of these causes since it is often the most difficult to find.

Q. What causes the engine to stop suddenly?

A. This is generally due to a failure of the ignition, owing to a break in the circuit caused by a connection dropping off, the switch suddenly opening under the vibration, or some part of the wiring becoming short-circuited. Clogging of the fuel line or of the carburetor nozzle or an empty tank will also result in the engine stopping. Where the stoppage is due to failure of the fuel supply from any cause, the engine will not usually come to as sudden a stop as when the ignition fails. The contacts in the breaker box of the magneto may have stuck together. If the cooling or the lubricating system fails, it will also take more time to bring the engine to a stop and there will be noises that give ample evidence of the cause of the trouble. The engine should be shut off the moment these noises occur for otherwise it will be forcibly stopped by the binding of the pistons, thus putting the engine out of commission.

ENGINE NOISES

Q. How are the different engine noises that signify trouble in the operation of the motor characterized?

A. Experienced motor mechanics give a different term to each one of several distinct classes of noise indicating faulty operation, such as knock, hammer, pound, and slap, and to the ear that is familiar with them each can be distinguished.

Q. What do these different noises signify to the experienced ear?

A. A knock is the first indication of looseness in a bearing, usually a connecting-rod big end, and the sound is generally that of a sharp metallic blow. When it is allowed to develop or when looseness in the crankshaft bearings develops, the sound becomes louder but not so sharp and is more aptly described as hammering, owing to its similarity to the blow of a sledge. Pounding is caused by preignition and by overheating and is so violent as to rack the whole motor very badly. Slap is the result of worn pistons, the skirts or lower ends of which are banged against the cylinder walls every time the motor fires. The noise produced is very similar to that of a knock and is often mistaken for the latter, though an experienced mechanic will seldom go wrong on this. In addition to the noises mentioned, there is another that is readily distinguished by the experienced ear, and that is the clatter caused by a loose valve motion, indicating that an excessive amount of clearance has been allowed to develop between the valve tappets and stems or in the rocker arms. To the inexperienced ear all strange noises will be *knocks* and it may seem to be drawing too fine distinctions to differentiate between knocking, hammering, and pounding, but familiarity with a motor will enable the operator not only to make these distinctions but to know as well what causes the different noises.

Q. Which of these noises calls for immediate attention on the part of the operator to prevent damage to the motor?

A. A very good rule to follow is to shut the motor down the moment any of these noises is heard and correct the trouble, but those that call for immediate attention to prevent serious damage are hammering and pounding. The first indicates a very loose bearing, which may result in a broken crankshaft if allowed

to run a moment longer than necessary, while pounding not only imposes exceedingly heavy stresses on every part of the motor but may also be the first sign of failure of either the cooling or the lubricating system. The cause may be nothing more serious than lack of sufficient water when burning kerosene or the fact that the spark lever may be advanced too far.

GOVERNOR

Q. What causes the engine to race when the load is thrown off?

A. The governor needs adjustment, or the connection between it and the throttle has parted.

Q. What attention does the governor ordinarily need?

A. This depends largely upon the type of governor. Some are housed in and the lubrication provided for by filling the housing with oil; such a governor needs very little attention, except to adjust it when it permits the engine to idle too fast. An adjusting screw is provided for this purpose. With the engine running, turn the screw gradually until the engine slows down to a point where it idles satisfactorily. The governor spring weakens in time, and the adjustment is provided to permit of increasing the tension. Apart from this, the only regular attention required by those types which are not automatically lubricated is to oil the bearings at regular intervals and see that the connecting linkage is in good order.

CLUTCH AND TRANSMISSION

Q. What provision is made for taking up wear in the clutch?

A. The friction surface, which is usually asbestos on a wire foundation, should be replaced when worn sufficiently to require it. After considerable service the spring pressure may let up sufficiently to cause unsatisfactory operation of the clutch. An adjustment is provided for increasing the tension of the spring, and this should be tightened just enough to make the clutch hold under load; but it is not good practice to attempt to make up for a badly worn friction facing by increasing the tension of the spring. Replace the facing first. This, of course, does not apply to the type employing metal to metal contact surfaces. Apart

from this, the chief attention required is lubrication, which should be carried out in accordance with the manufacturer's instructions, some clutch mechanisms calling for oil as much as two or three times a day.

Q. Is it good practice to let the machine stand with the clutch out of engagement?

A. No; as it only weakens the clutch spring and shortens its life. Whenever the machine is to stand more than a few moments, the gears should be shifted to neutral and the clutch allowed to engage. It is particularly bad practice to let the machine stand over night with the clutch out of engagement.

Q. Are a worn friction facing and a weak spring the only causes of a slipping clutch?

A. Allowing oil or grease to fall on the friction faces of the clutch will cause it to slip badly.

Q. What attention does the transmission require?

A. Maintain the oil level as indicated in the manufacturer's instructions and use only the oil called for by the latter. Drain as often as instructed, and wash out with gasoline or kerosene before refilling. This is usually two to three times a season, though some types may require it oftener. When the case has been cleaned out, inspect the gear teeth carefully for breaks, and see that any chips or foreign matter are removed. By filtering the old oil through several thicknesses of cloth, it may be used for other farm machines which do not require the same high degree of lubrication as the tractor.

Q. Does the differential require any special form of attention?

A. The differential is frequently combined with the transmission, so that it is lubricated by the same supply of oil. Where it is separate from the transmission, the attention required is the same as that just mentioned for the transmission.

HOUSING TRACTOR

Q. Does it pay to build a special shelter for a tractor?

A. It will undoubtedly be found a good investment, since the cost of a building large enough to shelter the tractor and provide a working bench beside it will usually be less than the added depreciation incurred by leaving it exposed to the weather.

Q. When the tractor is put up for the season, what attention should be given it?

A. Before putting the machine away for the winter, the valves should be ground, the bearings adjusted, the valve mechanism and the magneto overhauled, the oil drained from the crankcase and the transmission, and the latter washed out and provided with a fresh supply of oil. Wash the cylinders and pistons by putting a pint or more of gasoline in each cylinder and running the motor for half a minute. Then put a pint of fresh oil in each cylinder and turn the motor over by hand a few times to spread it over the surfaces; otherwise, the cylinders and pistons may rust. Coat all exposed parts with grease and cover the machine with a tarpaulin or old canvas. Make a list of all replacement parts necessary and order them at the time the machine is put away in order that they may be installed during the winter.

STANDARD UNITED STATES ARMY TRUCK
Courtesy of The White Company, Cleveland, Ohio

COMMERCIAL VEHICLES

INTRODUCTION

Development of Field. While the development of the commercial car was slow at first owing to the numerous shortcomings of early types, it has advanced with wonderful rapidity during the past few years and bids fair to supersede, in a comparatively short time, the use of the horse-drawn vehicle for business purposes, not only in the large cities but also on the farm. As in the case of the pleasure car, Europe led in the development of the automobile for transportation purposes, chiefly with military necessities in view, as without power-driven vehicles it would be impossible to move the enormous food and ammunition supplies required by an army of present-day proportions. However, American manufacturers have advanced so rapidly in the production of commercial cars during the past few years that in 1916 the registration of New York City alone showed a greater number of these vehicles than were reported by the census of 1915 for the whole German Empire and more than half the number reported in service in Great Britain during the same period.

Scope of the "Commercial Vehicle". It is important to know the reasons for the revolution which is now in active progress, as well as to become familiar with the prevailing practices in America and abroad in the construction, operation, and maintenance of that large and varied class of automobiles employed exclusively for business purposes. Regardless of type, class, or method of propulsion, these are commonly referred to as "commercial vehicles". This classification embraces not only motor delivery wagons and trucks for the transportation of merchandise, but also taxicabs, omnibuses, sightseeing vehicles, motor road trains, farm tractors, emergency repair or tower wagons for street-railway service, and also vehicles for special municipal service—ambulances, patrol wagons, fire engines, street-sprinkling and garbage-removal wagons, and the like. In fact, it may be said that any automobile not devoted to pleasure is a commercial vehicle, and, as was to be expected, the first types of these

vehicles were merely pleasure cars transformed to suit the needs of the occasion. To a certain extent, this still continues to be the case.

Standard Design. Whether it be electric-, steam-, or gasoline-driven, the general design of the motive power, as well as that of its transmission to the driving wheels, is practically the same in the commercial vehicle as it is in the pleasure car, except that the chain drive has now almost disappeared on the latter, and all the component parts—bearings, frames, axles, steering gear, and compensating mechanism—are the same. In other words, the chassis in both cases is composed of similar members. For the sake of brevity in the present treatise, it is assumed at the outset that the reader has become familiar with motor-car engineering so far as it relates to pleasure-car construction; that he understands, from previous study and the actual handling of machines, the *theory* of the operation of the internal-combustion engine; that he is conversant with the distinguishing characteristics of the several types of engines as well as with their advantages and limitations; and that he is acquainted with the types of transmission systems ordinarily employed on pleasure cars—in brief, that he understands any reference to component parts, to their functions, and to their relation to one another, without the necessity of explanation.

In common with the pleasure car, the commercial vehicle is capable of traveling at various speeds wherever road conditions will permit it to go. Both comprise in a single entity a wheeled vehicle suitable for transportation purposes, fitted with an independent, self-contained power plant, and both present the same engineering problems so far as they relate to the construction of the motor, its control, and the transmission of its power to the road wheels, the design of the running gear, and the control of the vehicle itself. Divergence in practice is encountered with the consideration of the purposes for which each vehicle is designed. The pleasure car is not intended to be a very efficient vehicle. Its carrying capacity bears a comparatively insignificant ratio to its total weight, and, usually, the car is not designed to work under the same severe and continued conditions of service that are the first requirements of the commercial vehicle It must be capable of high speed with its maximum load of passengers and must combine reliability with endurance to an extent sufficient to meet the demands of its owner when on pleasure bent.

Classification. In order to make the subject as clear as possible and to facilitate reference on the part of the student, industrial motor vehicles as a whole have been classified, first, by their motive power; and second, by the uses for which they are intended. Thus there are, today, in the order of their relative importance:

Motive Power	Electric vehicles Gasoline-driven vehicles Gas-electric vehicles Steam vehicles
Types of Vehicles	Industrial electric trucks Delivery wagons Trucks, vans, and similar freight carriers Passenger vehicles—stages, busses, taxicabs, sight-seeing cars, etc. Municipal vehicles—patrol wagons, ambulances, fire apparatus, garbage-removal wagons, street sprinklers, etc. Special types—railway tower wagons, emergency repair wagons, farm tractors, road trains, etc.

This classification has been made advisedly, for, though kerosene and alcohol are being experimented with as fuels for the internal-combustion engine and particularly for commercial purposes, by far the greater majority of types marketed at present are driven by gasoline fuel.

Each of the foregoing principal divisions is susceptible of further subdivision, but this is neither necessary nor desirable. Commercial motor vehicles are now built for almost every conceivable purpose involving freight hauling or the transportation of passengers and include many special uses, such as hauling huge reels of telephone cable and drawing the cable through the underground conduits, transporting and hoisting safes and pianos, delivering coal with special dumping wagons, and the like. They differ only in the special equipment with which they are provided for the service in view, and, as their construction otherwise is the same, it would only lead to confusion to attempt to consider them separately.

ELECTRIC VEHICLES

Range of Use. Owing to the general recognition of its simplicity and economy, which has been brought about by a co-operative propaganda fostered by the electric lighting and power companies,

the growth of the use of the electric commercial vehicles during the past few years has been little short of phenomenal. One New York firm alone uses nearly 350 electric delivery wagons, several have nearly 100, while no fewer than forty-five have "fleets" of 10 cars or more. All told, there are several thousand electric vehicles in New York City and more than 100 garages and charging stations, while the demand for current has been so great that the minimum for charging batteries has recently been reduced to $10 per month. Current is supplied at a preferred rate under special contract, which calls for the charging of the batteries during those hours of the night when the load on the central stations is lowest.

Advantages of the Electric Type. *Simplicity.* One of the chief advantages of the electric vehicle, when judged from the purely commercial point of view, is its great simplicity, which, to a very large extent, solves the labor question that has proved such a deterrent to the adoption of the gasoline vehicle for commercial service. As the duties of the driver of an electric vehicle do not extend beyond its actual starting, stopping, and guidance while under way, anyone who has been accostumed to the use of horses can master its operation in the course of a few hours. This also appears to be equally true of men who have never driven any type of vehicle previous to their taking the wheel or steering tiller of an electric. Apart from the actual mechanical control of the vehicle, the driver's only other care is to keep informed as to the state of charge of the battery by watching the voltmeter, in order to prevent running the car with the batteries exhausted, as this is very detrimental to their continued usefulness. However, as the batteries of most commercial vehicles are charged every twenty-four hours and the car run is planned to lie within its traveling radius on a single charge, with a factor of safety allowed in addition, this is not a very onerous duty. The further requirement of noting the current consumption on starting and running, as indicated by the ammeter, in order that any defect in the operation of the running gear of the car may be detected and remedied, is also a very simple one, so that an unskilled driver is available at a correspondingly lower charge for labor cost in the operation of the vehicle. The adoption of the ampere-hour meter showing the actual consumption of battery energy has simplified the task of the driver still further.

Efficiency and Long Life. Broadly speaking, short runs with many stops are the province of the electric, so that probably 80 per cent of all average city deliveries come within its economic field. Its labor cost is much lower than that of the gasoline car, since an unskilled hand can operate it efficiently, while one man at the garage can take care of nearly twice as many electrics as of gasoline cars. The electric is easier on tires, owing to its reduced speed, insurance rates are lower, and its depreciation can be figured on a much more favorable basis, as it has been shown to have an average effective life of ten years. The fact that all its moving parts revolve has a most important influence on its low maintenance cost and reliability, many electric trucks showing an average of 297 days in service of the 300 working days in a year.

Power Efficiency. The amount of power available on a single charge of the batteries without unduly increasing the weight is so limited that in the design of the electric great care must be taken to eliminate friction and other sources of power loss at every possible point. This is further necessitated by the gradually decreasing efficiency of the batteries with age. Starting with 80 per cent when new, the efficiency may drop rapidly to 50 per cent or below unless the batteries are properly maintained, which is likewise true of the transmission efficiency of the running gear of the vehicle; so that while unskilled labor may be employed for the operation of the vehicles this is not the case where their maintenance is concerned. Power losses due to the tires are also an important factor, and as the pneumatic tire can very seldom be considered for commercial service, the same degree of efficiency is not obtainable from the business electric wagon as from the pleasure type employing the same motive power. Road conditions must also be considered—despite the fact that electrics are employed almost exclusively for city or near-by suburban service—as mud, snow, and ice in winter, and poor pavements at any time cause an increase in the current consumption.

ELECTRIC DELIVERY WAGON

General Specifications. Whether considered from the point of view of design and construction or from that of operation, the electric delivery wagon is, without doubt, the simplest vehicle in the commercial field. As already mentioned, its operation may be

mastered in a comparatively short time, either by the ex-horsedriver or by a person who has never had any experience in the control of a vehicle, so that the labor cost—always an item of importance in this field—may be materially reduced without fear of the equipment suffering in consequence. It is usually customary with manufacturers of these vehicles to adopt a standard form of design, which is employed throughout in every size listed by the same maker, the only differences being those of dimension, load capacity of the vehicle, and capacity of the battery to take care of the increased weight.

Package delivery wagons and express wagons of the electric type have a useful load capacity ranging from 1000 to 2000 pounds, though a very few of less than 1000 pounds' capacity were employed at first. The 40-mile run is standard and is based on an average speed of 10 to 20 miles an hour, including stops, as the necessity for frequently stopping and re-starting the car in delivery service has an important bearing on the mileage of which the car is capable on a single charge. The latter is naturally figured on the maximum efficiency of the car as a whole, so that in practice this is seldom fully realized, owing to the deterioration of the batteries in service.

Design. The electric has progressed through the stages represented by the angle-iron frame, the armored wood frame, and the modifications of the two as employed on gasoline cars to the now generally current type of pressed-steel frame. This frame has the advantage of being extremely strong for its weight. It is composed of side and transverse members produced in hydraulic presses directly from steel plates of about $\frac{5}{16}$-inch thickness, these members being riveted together and further reinforced by gussets at the corners. On account of the height of the vehicle, the frames are made perfectly rectangular and without either a drop or narrowing forward.

The types of suspension employed also show the same variations as are to be found in the gasoline-driven cars, some of the smaller electrics having the full elliptic springs ordinarily employed on wagons, while intermediate and heavy vehicles have either straight semi-elliptic springs front and rear or a half-platform type of suspension in the rear. A study of the Baker and General Vehicle types of delivery wagons and trucks will show how closely they approach, as a whole, to what is considered general practice in the automobile field.

Because of the heavy loads carried and of the fact that solid tires are used, the entire running gear has to be planned on a very liberal scale. This is likewise true of the springs. While it is desirable that the latter afford as much protection to the mechanism as possible, sufficient stability to carry the load is of more importance than flexibility, as the comparatively slow speeds do not occasion the violent shocks met with in the pleasure car.

MOTIVE POWER

Type of Motor. As already mentioned, the motive power of the majority of smaller electric vehicles consists of a single motor, and, in several makes, such as the Waverley, G.V., G.M.C., and Detroit, this practice extends to heavy units, with a corresponding increase in the efficiency of the vehicle as a whole. In order to keep down the weight as well as the space occupied, these motors are very small for their power output, and consequently have to be wound for high rotative speeds. They are usually of the series type of the General Electric or the Westinghouse make and are designed to carry heavy overloads for short periods, to enable the car to pull out of a bad place, to start with full load on a heavy grade, or to meet similar emergencies, the motor, under such conditions, delivering an amount of power greatly in excess of its normal rating.

Motor Suspension with Chain Drive. Since the use of spur-gear drives has decreased, the motor is usually suspended from the frame by means of transverse members riveted to the side rails and is placed near, or slightly forward of, the center of the chassis, in order to give the best distribution of weight. This is an advantage not obtainable when the motors are hung from the rear axle or too close to it. In view of the high speed at which the motors run—1800 to 2000 r.p.m. or more—a reduction in two stages is necessary to avoid the employment of excessively large sprockets. The first step is from the motor to a countershaft by means of a single silent chain of the Morse or the Renold type, the motor being suspended in such a manner that it may be moved a short distance one way or the other to permit the adjusting of this chain to the proper tension, Fig. 1. The large sprocket on the countershaft, which serves to cut down the speed in the proportion of about 1 to 5, also embodies a differential, or compensating, gear of the usual bevel or spur type, thus making

it possible to employ a solid one-piece axle instead of weakening the latter by inserting the balance gear in it. This is an important feature, as the rear axle must bear 60 to 70 per cent of the total weight of both the car and the load. From the countershaft, chains are run to each of the driving wheels. The relative positions of the countershaft and the rear axle are maintained by heavy adjustable radius rods, attached forward to the outer ends of the countershaft and, at the rear, to the axle. These rods take the stress of the drive off the

Fig. 1. Motor Suspension and Silent-Chain Drive on Baker Trucks

springs and counteract the tendency of the chains to draw the rear axle toward the countershaft, under the pull of the motor.

Motor Suspension with Shaft Drive. On light delivery wagons of the shaft-driven type, three methods of motor suspension may be noted. In the first method, the motor is placed just forward of the rear axle, its housing being practically integral with that of the axle. Either a worm drive permitting of a single-speed reduction or a two-speed gear through spur gears is employed. As the motor moves with the axle and their relations are fixed, flexible joints are not required. A modification of the first method consists in placing the motor under the car at about the center and mounting it on a flexible suspension so that it can move under stress without disturbing its alignment; while the third method provides for taking such stresses on universal and slip joints interposed between the motor and the rear axle.

Fig. 2. Chassis of 4000-Pound G. V. Electric Delivery Wagon

The relative locations of the various essentials of a delivery wagon of the single-motor side-chain-drive type are clearly shown in Fig. 2 that illustrates a G.V. chassis of 4000 pounds' capacity, this being the same except for the difference in size.

Worm-Gear Transmission. While the power is transmitted through a combination-chain drive, i.e., silent chain for the first reduction and roller chains for the final drive, on the majority of delivery wagons, the practice of utilizing the worm drive, which has recently been adopted on the pleasure cars, has also been taken up in this field on the light vehicles. An example of this is represented by

Fig. 3. Rear Axle of Commercial Electric Delivery Wagon

the G.V. 1000-pound delivery wagon, equipped with a single motor driving through a propeller shaft having two universals and with a David Brown (British) type of worm-gear rear axle. On machines of this class, it is customary to mount the motor on a flexible support, which permits it to adapt itself to variations in the angularity of the propeller shaft, thus reducing the load imposed on the universal joints and, at the same time, avoiding the effects of torsional stresses on the motor. As the location of the motor is such as to prevent the suspension of the battery below the frame in the usual cradle, it is carried forward under a bonnet, or hood, and the wheel-base of

Fig. 4. G.M.C. Chassis with Combination Shaft and Chain Drive

the chassis correspondingly lengthened. This is not the case with the Commercial worm-driven delivery wagon, as in this instance the motor is placed almost directly on the rear axle, as shown in Fig. 3, thus eliminating the propeller shaft and the necessity for universal joints. The spring suspension of the motor will be noted protruding above its forward end.

Fig. 5. Motor, Drive Shaft, and Jackshaft Assembly for G.M.C. Electric Wagon

Shaft and Chain Transmission. The G.M.C. (General Motors Company) electric embodies a combination of shaft and chain drive, as shown by the chassis, Fig. 4. This drive incorporates an ingenious

Fig. 6. Details of Motor Mounting, Brake, and Drive, G.M.C. Electric Delivery Wagon

feature consisting of the use of a spring steel shaft, as shown by the detail view, Fig. 5. The design of these cars, as shown by the chassis, is standard for all capacities ranging from a 1000-pound delivery

Fig. 7. Chassis of Waverley 5-Ton Electric Truck, Showing Battery Installation

wagon up to a 6-ton truck, and, in each case, the section of this shaft is calculated to transmit the power necessary, with a predetermined degree of flexure in starting, which serves to cushion the mechanism

as well as the tires. The pin attachment at the motor and the bevel-gear-driven countershaft eliminate the necessity for universal joints in this member while still permitting a rigid mounting of the motor on its sub-frame. As will be noted in Fig. 6, which shows the details of the complete drive, this sub-frame is carried in bearings on a tubular transverse member, thus allowing for relative movement in a longitudinal plane, the shaft itself compensating for torsional stresses.

Unit-Wheel Drives. Mention has already been made of the abandonment of two-motor drives on comparatively light cars, as well as the successful employment of a single motor on vehicles up to 5 tons' capacity, as in the case of the Waverley 5-ton chassis,

Fig. 8. Two-Motor Axle with Spur-Gear Drive, Commercial 2-Ton Truck

Fig. 7. The Commercial electric is an exception to this in that it shows the successful employment of two motors on cars as small as one-ton capacity. The rear axle of this car is a complete self-contained unit, as will be seen upon referring to Fig. 8 illustrating the drive of a 2-ton Commercial. The form of mounting employed is clear in the illustration, while Fig. 9 shows the details of the gear reduction between the motor and the driving wheel. This concern also makes a four-wheel drive, which is employed on vehicles of 3½ to 7 tons' capacity. On these machines, both front and rear axles are alike. One of them is illustrated in Fig. 10, in which it will be noted that the motor and the driving wheel are an integral unit pivoted in

the axle to permit of utilizing all four wheels for steering. The speed reduction in this instance is simply a double spur-gear train meshing with an internal gear cut on a drum in the rear wheel.

Couple-Gear Truck Drive. A particularly ingenious example of the ease and directness with which electricity lends itself to special

Fig. 9. View of Spur-Gear Reduction of Commercial Electric Drive

forms of construction is to be found in the drive of the Couple-Gear truck, so called because all four wheels are not only driven by electric

Fig. 10. Two-Motor Axle of Four-Wheel Drive of Commercial Heavy Trucks

motors but are utilized for steering purposes. These vehicles are built as straight electrics, using a storage battery as the source of

current; and as gas-electric vehicles, a gasoline engine and generator forming the power plant, the remainder of the design and construction being the same in both cases. Fig. 11 illustrates the detail of the axle design employed, each wheel being carried on a steering

Fig. 11. Couple-Gear Axle for Unit-Wheel Drive

spindle, and all four wheels coupled to act in unison, permitting the car to turn in a very short radius. The parts shown on the right-hand spindle in the illustration are the fields of the motor, the wind-

Fig. 12. Dismounted Couple-Gear Truck Wheel, Showing Motor Parts

ings being just visible in the armature tunnel. They are made in this form, as the motor is practically a part of the wheel.

The motor is built directly into the wheel, as will be apparent from the illustration of a dismounted wheel shown in Fig. 12. The

motor is of bipolar type, designed with flat fields in order that it may fit within the wheel without unduly increasing its section, and is held by its attachment to the axle. The wheel accordingly revolves about the motor, being driven by the two small pinions which are noticeable on opposite ends of the armature shaft and which mesh with the circular racks attached to the periphery of the wheel. The brushes are carried in a yoke bolted to the outer half of the field casting, so

Fig. 13. Walker Electric Chassis, Showing Combined Motor Axle

that the removal of the latter makes everything accessible. The cables for the motor current are led through the hollow axle. Apart from this feature and the employment of a four-wheel steer, the vehicle itself follows more or less conventional lines.

Balanced Drive. The transmission on the Walker cars, known as a "balanced drive", is another radical departure from current practice in this respect. These cars are built in capacities ranging from 750 to 7000 pounds and have been in successful service for a

number of years. As will be noted in Fig. 13, a single motor is employed, and it is built practically as an integral part of the rear axle, the housings of which form the fields. The armature of the motor is at right angles to the driving wheels, and its shaft is extended both ways to form the drive. At the outer ends, this shaft carries small spur pinions which mesh with two large gears. The latter,

Fig. 14. Details of Walker Electric Wheel Drive

in turn, mesh with an internal gear bolted to the inner face of the steel rims of the driving wheels themselves. The detail of this is made plain in Fig. 14, showing one of the wheels with the outer protecting disc removed. It will be apparent that this constitutes not only an unusually compact motor unit and transmission, having the great advantage of being always in direct line with its drive, but that it likewise dispenses with a differential, as the wheels themselves are balance gears.

CURRENT AND CURRENT CONTROL

Battery Equipment. As the motors commonly employed are wound to take current at 80 to 85 volts, the battery consists of 44 cells, divided into three or four groups of cells held in separate oak boxes, or "trays", as they are termed, to facilitate handling. This voltage is standard, regardless of the size of the vehicle, the latter being compensated for by changing the capacity of the battery. Thus, for light delivery wagons, each cell contains three positive and four negative plates of medium size, giving an 85-ampere-hour discharge capacity, while a 1000-pound wagon is equipped with a battery having nine-plate cells with a capacity of 112 ampere hours; a 2000-pound wagon, eleven-plate cells of larger dimensions, giving 140 ampere hours; and so on in accordance with the size of the vehicle and the load it is designed to carry. Most electric vehicles have the battery underslung, i.e., carried in a cradle supported from the frame of the chassis. The cradle is enclosed in a battery box for protection against mud and water and has hinged doors at the ends through which the battery may be introduced or removed. By this arrangement, the weight of the battery, which is the heaviest single item in the entire construction, is distributed evenly between the forward and rear wheels, which leaves the entire floor space of the wagon available for the load. In special types, such as the G.V. 1000-pound worm-driven delivery wagon, the usual practice in the pleasure-car method of carrying the battery under a hood forward is followed. All the wiring between the battery, controller, and motor is carried beneath the floor and is protected from injury by running it through iron conduits.

Controller. In the case of delivery wagons and light trucks, the controller itself is placed either beneath the seat or under the footboards and is similar in construction to those employed on street cars, but much smaller in size, owing to the low voltage and comparatively small amount of current to be handled. It is operated by a small hand lever and usually provides four speeds ahead and two reverse, all of which are obtainable by moving the same lever, although a special lock, or catch, must first be operated before the vehicle can be moved backward. This usually takes the form of a pedal, or kick plate, which may be depressed with the heel and must frequently be held down while reversing. When released, it auto-

matically returns the controller to the ahead position, in order to prevent the vehicle from being backed inadvertently.

Departures from the usual method of placing the controller are to be found in some of the medium-capacity vehicles, such as the Baker, in which the controller is located on the steering column just below the footboards; in the Urban, it is placed in a special dash compartment, the lever being on the steering wheel. This compartment also contains the ampere-hour meter, a type of instrument which records in watt hours the amount of power drawn from the battery and, at the same time, indicates the available amount remaining at any time. Ampere-hour meters are coming more and more into general use on both pleasure and commercial electrics, and a detailed description of the instrument and its use is given in connection with electric pleasure cars. In service, this dash compartment is protected by an aluminum plate through which the dial of the meter appears. On the Commercial, the controller is mounted directly on the steering column and is operated by a second smaller wheel, Fig. 15. The controller itself is thus above the footboards, and by the removal of the protective housing shown becomes very accessible. In cases where it is necessary to provide for handling heavy currents, a railway type of controller is employed.

Fig. 15. Commercial Electric Controller on Steering Column

A novel controller installation that gives instant accessibility is found on the G.M.C., as shown in Fig. 16. The controller proper, as well as all wiring terminals, fuses, and meters are mounted under a short hood, the resistance being suspended just beneath the controller, while the charging receptacle is below the center of the bumper. This view illustrates the forward side of the dash, while Fig. 17 shows the side facing the driver. The connection between the control lever

over the steering wheel and the controller is through a shaft and a bevel gearing, as shown in Fig. 16. In the illustrations, this lever is

Fig. 16. Controller Installation of G.M.C. Electric Delivery Wagon

at the neutral position, successive movement from this point forward giving five speeds ahead and two reverse speeds backward. The

Fig. 17. Simple Control of G.M.C. Electric

G.V. control is equally compact, being mounted in a steel box forming the driver's seat, as shown in Fig. 18. The safety switch and

the plug connection for an inspection lamp are seen on the outside at the left. Inside are, first, the switch connections, then the fuses, and, next, the fingers of the controller. At the upper right hand (driver's left) is the control lever, while just visible below the box is the resistance.

Safety Devices. In view of the fact that the average driver of an electric delivery wagon or a truck is either a graduate from the reins or has had no experience in handling vehicles at all, it has become customary to provide safety devices which, to a large extent,

Fig. 18. Controller Box of G. V. Electric Delivery Wagon

prevent accidents that might otherwise result from this lack of experience.

Cut-Out Switch Connected to Brake. The brake is usually interconnected with a cut-out switch which automatically shuts off the power independently of the controller simply by the application of the former. While the brakes are sufficiently powerful to stop the machine even with the current on, forgetting to shut off the current would either blow out the fuses or result disastrously to the motor.

Circuit-Breaker and Hand Switch. A circuit-breaker is provided on some cars to obviate the necessity for frequent replacing of the fuses, this being the usual practice in street railway and other electric work. Frequently, a hand-operated cut-out switch is also installed

to permit of inspecting or working on the controller without the necessity of disconnecting the battery, as a failure to do so where no switch is provided is apt to result in painful burns, owing to the large amount of current.

Charging Circuit-Breaker. Another safeguard is an automatically operated circuit-breaker to protect the battery from being overcharged. This is used in connection with the Sangamo ampere-hour meter, which is described under the head of "Meters". Unlike the Anderson device described previously, which can be employed only where connection can be had to the field coils of the generator, this circuit-breaker operates exactly the same as the circuit-breaker in a generating station, which opens the line when an excess amount of current passes through it, except that in this case its operation is not controlled by the number of ampere turns on the circuit-breaker itself, but by a trip switch actuated by the ampere-hour meter when its dial records that the battery is fully charged.

Devices to Prevent Accidental Starting or Tampering. Devices are provided to prevent the accidental starting of the vehicle when not anticipated by the driver; also to guard against tampering by the ubiquitous small boy. On the G.V. 1000-pound worm-driven delivery wagon, for example, the emergency brake cannot be locked on except when the "running switch" is in either the neutral or the charging position, and cannot be released until thrown into the running position. Moreover, this switch can be thrown to the running position only when the controller is at the "off" point, or neutral position. The interconnection of the brakes and the controller "throw-off" allows the driver to use both hands for steering, in an emergency and, at the same time, to cut off the power and apply both brakes with his feet. This emergency-brake lock compels the driver to turn off the current by throwing the running switch to neutral when leaving the car; it also prevents the brake from being released by an unauthorized person, as the driver can take the switch handle with him. As the brake cannot be released until the switch is thrown on, the driver is reminded of that fact. The running-switch lock prevents the accidental starting of the vehicle, which might happen if the controller had been tampered with during the driver's absence, and if, upon his return, he threw the running switch on without first looking at the controller handle.

Brakes. Owing to the comparatively low speeds, the braking equipment in the earlier designs usually consisted of a single set of drums attached to the driving wheels. Against the inner faces of these steel drums bronze shoes were expanded by means of a pedal and the usual brake rigging beneath the car. As was the case in practically all early chain-driven cars, the braking drums carried the driving sprockets on their outer faces.

But in this, as in many other essentials, practice has been improved along the lines followed in the gasoline car. It is now customary to employ two sets of brakes, one for regular service and one for emergencies. Usually, both sets of brakes are carried in drums on the driving wheels, either side by side or concentrically, a friction facing of asbestos on a woven-wire foundation being employed. In some cases, the service brake operates on a drum carried on the armature shaft of the motor.

Tires. While solid rubber tires are most generally employed, they are not necessarily so, as pneumatic tires are to be preferred where the merchandise to be carried is of a light or fragile nature or where speed is one of the chief features of the delivery service. They not only reduce the liability to breakage, but also lessen the cost of maintaining the vehicle in repair. However, as there are comparatively few branches of commercial service in which the pneumatic tire is economically practicable, its use is very limited. The solid tires employed vary in size from two to four inches, and for weights in excess of the capacity of the latter, they are used in twin form on the rear wheels.

SPECIAL FORMS OF THE ELECTRIC

Electric Tractors. The huge street-cleaning or garbage-removal truck, shown in Fig. 19, is drawn by a 5-ton G.V. electric tractor, the combination being along lines somewhat similar to the front-driven electrics adopted by the Paris street-cleaning department for the same purpose, except that the latter have a two-wheel tractor and are fitted with a specially designed covered steel body. One use of the electric tractor built along the lines just referred to is shown by the Couple-Gear propelled steam fire engine, Fig. 20. Part of the battery is carried on the frame and the remainder is suspended beneath it, the power consisting of two Couple-Gear motor wheels

Fig. 19. Five-Ton G. V. Electric Tractor Hauling Garbage Wagon

mounted on steering spindles and operated by a street-railway type of controller which will be noted at the left of the driver. The entire power plant is a complete unit, which is bolted directly to the engine without further alteration than the removal of its front truck.

Fig. 20. Couple-Gear Tractor Drawing Steam Fire Engine

Industrial Trucks. One of the most important developments of the past few years has been the widespread adoption of the so-called industrial truck. In a broad sense, the term represents a classification rather than a type, as there are several different types of chassis built for this purpose. Probably the first of these to be placed in service was the Lansden dock truck, designed for handling cargo on steamship piers. In addition to this, there are baggage and mail trucks for use in railway depots, also truck cranes and tractor trucks, and it will be apparent that they are designed for service where no other form of power than electricity would be either convenient or permitted. The battery truck crane, the baggage truck, and the tractor trucks are merely modifications of the simple freight truck, their functions varying somewhat in each case. The baggage truck has a field of its own in the handling of baggage and mail, some being of the drop-frame and double-platform type and others having the battery and mechanism placed below the loading platform, which is made of railway-car height.

The simple industrial, or freight, truck is built in sizes and capacities suitable for moving loads on piers, in freight sheds, warehouses, factories, and industrial establishments generally. Its short wheelbase permits it to pass through congested spaces, going backward or forward with the same facility, while it is capable of ascending gradients of 10 to 25 per cent. On piers and at railway terminals it can deliver its load on the deck of a vessel or in a box car. The capacity of such trucks seldom exceeds 2000 pounds, this figure being found the practical limit for trucks capable of the widest range of action. The loading space of a truck of this capacity is 28 square feet, while the total area required for movement is only 34 square feet, the machine having an extreme width of 4 feet and an extreme length of 8 feet, so that an industrial truck can be operated wherever a hand truck can go, while the former will ascend grades impossible to the latter.

Fig. 21 shows a standard G.V. 2000-pound industrial truck, of which there are several hundred in use. Both the battery and the driving mechanism are suspended below the platform, which has rounded corners and is extended to protect the mechanism at every point. Its speed on hard level surfaces is 7 miles per hour; its average radius, 25 miles on one charge of the battery, the current consumption

for a full charge amounting to 6 to 8 kilowatt hours. For grades up to 10 per cent, only one motor is employed. When equipped with two motors, each rear wheel is driven by an individual motor geared to a housed spur gear fastened to the wheel. A spring-returned controller is used, the operating lever returning to neutral when released by the driver. The brake is also spring-operated and is normally set, so that in order to run the car the driver must keep the brake pedal depressed. A further safety precaution is an automatic cut-off

Fig. 21. G.V. One-Ton Industrial Truck Handling Freight

switch connected with the brake, so that in releasing the pedal of the latter the power is cut off automatically. In addition to this pedal, two operating handles are provided, one for the controller and the other for steering, the truck being capable of turning around in a 7-foot radius. In general freight-shifting service, the hauls averaging from 200 to 800 feet, each truck displaces from four to six men with hand trucks. The efficiency of these trucks is frequently increased by using them in connection with trailers and large numbers are employed in factories for transporting material from one department to another.

ELECTRIC TRUCKS

Classification. There is little, if any, difference in design between delivery wagons and trucks, the frames, axles, wheels, springs, and transmission simply being made heavier in proportion to the great increase in load to be carried, while there is a corresponding difference in the power of the motor or motors and in the size of the chains or other essentials of the transmission. As already mentioned, some makes, such as the Walker, adhere to the single-motor power plant even in sizes up to 2 and 3½ tons' capacity, and the G.V., Lansden, Waverly, and G.M.C., up to 5 and 6 tons, on the score of increased economy and higher efficiency, while others, such as the Commercial, employ two motors on vehicles as small as the 4000-pound size and four motors on larger trucks.

Next to the delivery wagon, in which electric power has scored a great success, trucks of 2-ton and 3-ton capacity are the most common forms of electric vehicles—though the 5-ton size has come into general use for brewery service—several hundred being run by brewers in New York, while one St. Louis company has nearly a hundred. Electric trucks of 6- and 7-ton capacity are also built. In order to obtain the increase in load-carrying capacity, the size of the motor must naturally be enlarged, with a corresponding increase in the power consumption, which calls for a very much larger battery. In order that the capacity of the battery may be sufficient to give the vehicle a practical radius of travel on a single charge without unduly adding to the weight, the speed is reduced, so that electric trucks of 2-ton capacity usually have an average speed of 8 to 10 miles an hour; 3-ton trucks, 6 to 9 miles an hour; while 5-ton trucks seldom exceed 7 miles an hour.

Characteristics of Chassis. The electrics listed by the General Vehicle Company afford an excellent example of a standard design of chassis applied to cars ranging from 1000 pounds up to 5 tons' capacity, the intermediate sizes being 2000 pounds, 2 tons, and 3½ tons. Naturally, the first two are delivery wagons and are capable of traveling 45 miles on a single charge of the battery at a maximum speed of 12 and 10 miles per hour, respectively. The 2-ton wagon, while capable of the same mileage, has a maximum speed of but 9 miles per hour. This is further reduced to 8 miles per hour for the 3½-ton truck, which has a radius of 40 miles on a charge, while the

5-ton truck travels only 7 miles an hour as a maximum and has an extreme radius of 35 miles on a charge. In every case, only a single

Fig. 22. Rear View of G.V. 4000-Pound Chassis

motor is used, and as the design in all other respects is also standard for all sizes, a description of the 4000-pound wagon will suffice.

Fig. 23. General Electric Motor

With the exception of the use of a single-motor drive, a large number of the parts employed are practically the same as those used

in other makes of electrics. The foundation of the entire car consists of a pressed-steel frame, to which are directly riveted the cradle for

Fig. 24. Rear Axle of G.V. 2-Ton Truck

carrying the battery, the spring hangers, and the supports for the countershaft bearings.

A view of the complete chassis will be found in Fig. 2. The view is taken from above and illustrates every essential except the battery. At the rear are the semi-elliptic springs, the solid-steel axle, artillery wheels with solid rubber tires and large driven sprockets, driving chains, the single motor suspended from a transverse tubular member on the frame, the enclosed silent-chain drive from the motor to the countershaft, the wiring in conduits from the controller to the motor, and the countershaft with its radius rods to equalize and maintain its distance from the rear axle. These rods also serve to

Fig. 25. Front Axle of G.V. 2-Ton Truck

take the stresses of driving off the rear springs. Just in front of the countershaft is the steel cradle for the battery trays; at the left, that is, at the front of the truck, is the steering gear, forward axle, springs, and wheels.

An excellent view of the entire bottom construction, which gives a clear idea of the arrangement of the power and the drive, is shown in Fig. 22, while the essentials comprising it are shown in detail in Figs. 23, 24, and 25. Fig. 23 is a G.E. multipolar, ironclad motor. Fig. 24 shows the rear axle, while the forward axle and its steering attachments are shown in Fig. 25. A 44-cell storage battery furnishes current at 85 volts, the motor being wound to operate economically at this voltage. The battery is in sectional form, in crates of such weight and size as to permit of easy removal or of replacement from either side of the vehicle. It is so arranged that it may be recharged without disturbing it; but, where two batteries are employed, a charged set may be easily and quickly substituted for the exhausted battery.

The controller is of the continuous-torque type which will permit of changing the motor speeds by degrees without interrupting the power between any of the steps. This gives a gradual and steady acceleration, without the jerk and strain so detrimental to the life and efficiency of every part of the vehicle. The motor is designed along the lines which have proved so successful in street-railway work. It has a very heavy shaft as well as a simple and durable brush rigging and is wound to show not only a high efficiency but also a high capacity for overload. The armature shaft, which is carried on annular ball bearings that tend to greatly increase the efficiency of the motor as a whole, is suspended on a transverse bar pivoted to the side members of the frame forward of the rear axle. This pivoted suspension keeps the motor shaft parallel with the countershaft throughout the entire range of chain adjustment and permits the use of an efficient silent-chain drive, which, as will be noticed in Fig. 2, is enclosed in an aluminum housing.

The countershaft is housed in and is carried on four taper-roller bearings inside the tube, the latter being held in self-aligning ball sleeves in hangers riveted to the sides of the frame. The two short driving shafts are connected by a spur differential and carry at their outer ends small sprockets for the roller chains to drive the rear wheels, the entire countershaft being a complete unit. It is driven by a silent chain of ample width running over a small pinion on the motor and over the gear of the differential. Altogether, this is a very efficient form of truck.

GASOLINE VEHICLES

GASOLINE DELIVERY WAGONS

Classification Limits. It will be found on a brief examination of the subject that this is a far more comprehensive heading than would appear at first sight, as it includes everything from the little three-wheeler up to the type known as the "light truck", but which is, in reality, also a delivery wagon with an open platform, or stake type of body. The range of carrying capacity is from one to two hundred

Fig. 26. Autocar Two-Cylinder Delivery Wagon

pounds up to one ton, or slightly more, as many delivery wagons and light trucks are built with a load capacity of 2500 pounds or even 3000 pounds.

Autocar. The Autocar delivery wagon, Fig. 26, affords an excellent example of a vehicle designed especially for the most severe business conditions. The motor is of the two-cylinder, horizontal, opposed, four-cycle type, the cylinder dimensions being $4\frac{3}{4}$-inch bore by $4\frac{1}{2}$-inch stroke, and is rated at 18 horsepower. The crankshaft is mounted on imported annular ball bearings, which not only add greatly to the efficiency of the motor as a whole, but do away with the attention necessary to adjust plain bearings. This construction,

which is far more expensive than plain bearings, also reduces the number of parts which are subject to damage should the driver neglect to provide sufficient oil. The lubrication system is entirely automatic in operation. Two flywheels are carried on the crankshaft, the forward one having its blades cast staggered so as to set up a strong current of air, thus eliminating the necessity of a belt- or gear-driven fan, while the rear flywheel carries the clutch. The importance of providing ample weight in the balance wheel is something to which insufficient attention has been devoted in the past, its influence upon the starting ability and the smooth-running qualities of the vehicle being extremely marked, especially where a two-cylinder motor is employed. Both flywheels on the Autocar motor are counter-weighted, and this, supplemented by a careful balance of all the reciprocating parts, makes an extremely smooth- and quiet-running motor with unusual starting and grade-climbing ability for its size.

The crankcase is split horizontally into two sections, the lower half carrying the cylinders, crankshaft, camshaft, and water pump, while the upper half carries the push-rod guides, the magneto, the oiler, and a gear for driving the water pump. The magneto and oiler are both driven through bevel gears and short shafts, reducing the possibility of failure in these two highly important essentials—ignition and lubrication—to a minimum. The upper section of the crankcase is readily removable, carrying its parts with it and thus giving access to the crankpin bearings without the necessity of dismantling the motor. A Bosch magneto with a fixed firing point is employed, thus taking this element of control out of the hands of the driver. Lubrication is by a force-feed oiler delivering oil through a sight feed to the crankcase, from which the pistons, crankpins, and main bearings are lubricated by splash. Both the magneto and the lubricator are simply attached to the crankcase by wing nuts so that they may be removed without the aid of tools. A hydraulic speed regulator, connected in the circulation circuit of the cooling water, controls a throttle placed in the intake manifold between the carburetor and the cylinders, limiting the speed of the motor to 1400 r.p.m. and that of the vehicle to 18 to 20 miles per hour.

A patented floating-ring clutch, which has been developed on the same make of pleasure cars and used for a number of years, constitutes the first step in the transmission. It consists of a bronze floating

ring, lined with cork inserts on its inner face, and is mounted on four keys on the inside of the rim of the rear flywheel, thus rotating with the latter. Two cast-iron rings, adapted to clamp the bronze ring when the clutch is engaged, are mounted on the clutchshaft which extends into the transmission case. Engagement is accomplished by a sliding trunnion and four toggle links, the motion of which is checked by a dashpot and a plunger. This insures gradual automatic action, entirely free from jerk, regardless of the care exercised by the driver. The addition of small springs to the floating ring eliminates all noise, whether the clutch be engaged or not.

Fig. 27. Autocar Double-Reduction Floating Rear Axle

Fig. 28. Rear View of Autocar Delivery Wagon

The transmission housing is all in one piece, except its cover plate, and has been so designed that all the shafts and gears may be removed without disturbing the housing itself. The shafts are large and are

Fig. 29. Autocar Engine and Transmission Mounted on Separate Sub-Frame

carried on adjustable roller bearings, while the gears have broad faces and heavy teeth. Three speeds forward and one reverse, operating progressively, are provided, lubrication being obtained by covering the shafts and gears with a bath of semi-fluid oil.

Fig. 30. Autocar Engine and Transmission—Plan View

Both front and rear axles have been designed especially to meet the requirements of the heavy service imposed upon them in carrying the load on solid rubber tires. The front axle is of the tubular type,

with extra heavy yokes for the steering spindles, which are made integral with the spring saddles. Adjustable roller bearings are employed in the wheel hubs. The rear axle is of the full floating type, with a double-gear reduction. A bevel pinion at the end of the propeller shaft meshes with a large bevel gear on a short transverse shaft, from which the drive is transmitted to the differential case by means of a pair of substantial spur gears, the method of mounting them being shown by Fig. 27. The complete axle, as well as the spring suspension, the brakes, and other details are shown in the rear view, Fig. 28.

One of the chief features of advantage on the Autocar delivery wagon is the mounting of the complete motor and transmission, barring the rear axle, on an independent sub-frame, as shown in Figs.

Fig. 31. Plan View of White Delivery Wagon Chassis

29 and 30. An illustration of the complete chassis would show every part of the power plant to be accessible by lifting the bonnet, while the complete unit, as shown separately, may be removed from the chassis and replaced by another. The rear view of the chassis, Fig. 28, shows the relative location of all the essential parts, including the gasoline tank, which is placed transversely on the main frame directly under the driver's seat. The frame is of pressed steel, perfectly rectangular and heavily reinforced. Two sets of brakes act on drums attached to the driving wheels, while the suspension consists of double-elliptic springs in the rear and semi-elliptic springs placed forward directly under the motor.

White. This may be regarded as a representative standard design, as will be evident from the photo of the chassis, Fig. 31, show-

ing that it differs from heavier-capacity vehicles of the same make only in being shaft-driven and having lighter dimensions. It is built in 1500- and 3000-pound sizes, the chassis illustrated being of the latter capacity. Single rear tires are usually fitted on the smaller car, and pneumatics are frequently employed to take advantage of the higher speed thus made possible, an example of this practice being illustrated by Fig. 32. Apart from the difference in dimensions and tire equipment, both sizes are the same, each being equipped with a $3\frac{3}{4}$- by $5\frac{1}{2}$-inch motor, the cylinders of which are cast in one piece,

Fig. 32. White Delivery Wagon with Light Top Body and Pneumatic Tires

with the intake and exhaust passages integral. This motor is rated at 30 horsepower and fitted with a compression release for starting. A single-nozzle water-jacketed carburetor supplied with hot air from a jacket on the exhaust pipe, a high-tension magneto for ignition, and a gear-driven centrifugal water pump comprise its auxiliaries.

GASOLINE TRUCKS

Load Efficiency Increases with Size. It will be apparent that above the 2-ton size the load efficiency increases, as, once a certain point is reached, additions to the weight caused by increasing the dimensions of the load-carrying space and adding to the power of the motor are disproportionately small as compared with the increase in

load capacity. For example, one truck of 3-ton capacity has a chassis weighing only 4500 pounds, which tips the scales at 5200 pounds completely fitted, or "all on"; on the other hand, another chassis for the same nominal carrying capacity, i.e., 3 tons, weighs 6000 pounds. However, as no standard for rating the load-carrying capacity of gasoline trucks has ever been attempted, and one maker's 5-ton truck is sometimes no larger than the 3-ton truck of another, it is often difficult to make comparisons that will be fair on a basis of catalogue weights alone.

MOTOR DETAILS

Design

Both the design and construction of internal-combustion motors for commercial use are along lines similar to those employed on pleasure automobiles except as modified by the requirements of the more severe service. This necessitates a higher factor of safety throughout, such as increased provision for lubrication and cooling; extra large bearing surfaces, which must be readily accessible for adjustment, except, of course, where antifriction bearings are employed; increased crankshaft dimensions; broad gear faces; and a considerably increased weight of flywheel in order that the motor may develop as high a torque as possible at low speeds. The greater amount of weight in the rim of the flywheel also eliminates motor vibration to a considerable extent and makes the engine run much more smoothly. Such variations of design as are usual in the pleasure-car motors are to be found in the commercial type; in fact, where a manufacturer builds both types, the same lines are followed in each case, the only practical difference being in the dimensions and speeds. It will be necessary, accordingly, to refer to only a few of the more representative makes.

Long Stroke, Low Speed. Generally speaking, a commercial motor is of the long-stroke low-speed type, some idea of the proportions being obtainable by the dimensions of the White and the Pierce-Arrow motors for 5-ton trucks. The former has a $4\frac{1}{4}$-inch bore by a $6\frac{3}{4}$-inch stroke, while the latter measures $4\frac{7}{8}$ by 6 inches. Similar small variations in dimensions are to be noted in practically every make, in conformity with the varying standards of compression and volumetric requirements adopted by their designers. This will

be apparent by a comparison of a few makes, such as the Locomobile, 5 by 6 inches; G.V. and Mercedes, 4.25 by 5.9 inches; Peerless and Kelly, $4\frac{1}{2}$ by $6\frac{1}{2}$ inches; Vulcan, $4\frac{3}{4}$ by $5\frac{1}{2}$ inches. No increase is made in motor dimensions above the 5-ton size, the extra carrying capacity being gained by higher gear reductions and lower speeds, the Vulcan motor mentioned being employed on both the 5- and 7-ton sizes of that make. These motors are variously rated at 35 to 40 horsepower,

Fig. 33. Peerless 5-Ton Motor, T-Head Type

viz, Vulcan, 36 horsepower; White, 40; Kelly, 38.5; Peerless, 32.4; Pierce-Arrow, 38.

Causes of Variations in Ratings. The variation in the ratings is due to a number of causes, although one of the chief reasons is the differences in the practice followed, i.e., in some cases, the power stated is the maximum indicated horsepower based on the dimensions and worked out by the S.A.E. formula of $\frac{D \times N}{2.5}$, in which D is the bore, N the number of cylinders, and 2.5 an arbitrary constant derived from taking the speed characteristics of a large number of motors and striking an average representing a piston speed of 1000 feet per minute. In other cases, it is the result of actual brake tests

Fig. 34. White 40-Horsepower Block-Type Motor for 5-Ton Truck

Fig. 35. Pierce-Arrow Motor for 5-Ton Truck

and is accordingly based on the maximum r.p.m. rate of the motor; while in still others it is the power which the motor is capable of developing at the speed at which it is controlled by the governor, usually 800 to 1000 r.p.m., to give the best service from the truck of the capacity for which it is designed. For instance, the rating of the Kelly motor is based on a speed of 900 r.p.m., while that of the Peerless, Fig. 33, of the same dimensions, is its indicated horsepower figured according to the above formula. The White motor, Fig. 34, is an example of the L-head type; while the Pierce-Arrow, Fig. 35, like the Peerless already mentioned, is of the T-head type.

Accessories

Ignition. In every department of commercial-car practice, the designer aims to make the operation of the machine as nearly automatic as possible and to that extent to relieve the driver of any opportunity to exercise his discretion. The usual practice is to employ a magneto fitted with an automatic spark-timing device. This operates on the principle of the centrifugal governor and is controlled entirely by the speed of the motor, so that when the motor is stopped the spark timing is fully retarded and there is no danger from a "back-kick" as is the case where this precaution is inadvertently overlooked. As the motor speed increases, the occurrence of the spark in the cylinders is automatically advanced to correspond, thus relieving the driver of this important function and preventing the abuse of the motor in unskilled hands. The same slight differences in detail as found on the pleasure type are also found in the ignition systems of commercial cars.

Carburetors. Carburetors also are the same both in principle and construction as on the pleasure cars, except in instances where they have been specially designed for commercial service, in which case the modification applies to the construction. In view of the very general custom in this country of leaving the design of auxiliaries to the accessory manufacturer, the number of these instances is very small, so that in the majority of cases the carburetor manufacturer sells the same carburetor for either type of vehicle. To permit of the efficient utilization of lower-grade fuels, ample provision is usually made for heating the carburetor by a large warm-water jacket and a supply of hot air taken from a collector located on the exhaust pipe.

Cooling Systems. The so-called direct system, in which air is relied upon to keep the cylinder walls of the motor at a temperature that will permit of efficient operation without danger of seizing, was never attempted on commercial vehicles except in the lighter sizes. Most of these were light delivery wagons, although one make of 3-ton trucks employed a blower system for several years. However, air as the cooling agent without an intermediary in the form of a water circulation has been definitely abandoned on the commercial car. Both the principles and the operation are the same as on pleasure cars, due allowance being made for the more severe service by increasing the size of the pump, the section of the cylinder jackets, the area of radiating surface, and the diameter of the connections.

Radiator Construction. The radiator is the most vulnerable part of the truck, and precautions are therefore taken to protect it from injury. In order to be proof against the constant vibration and jolting, the gilled-tube type of radiator is employed in the majority of instances. Accidental damage is usually provided against by extending the frame and equipping it with a bumper, and further protection is sometimes afforded by mounting a heavy wire screen in front of it. This is done more frequently on honeycomb, or cellular, radiators, as they are liable to suffer severely when prodded with the steel-shod pole of a horse-drawn truck, and are difficult and expensive to repair. In the case of the gilled-tube type, only those tubes actually struck are likely to be damaged and they will frequently bend without rupture, while often nothing more serious happens than the bending and derangement of the cooling fins with which each tube is surrounded. These tubes are placed vertically and, in the case of the Reo 2-ton truck radiator, Fig. 36, are made demountable, so that a damaged tube may be easily replaced in a short time without the necessity for making any soldered repairs. It will be noted that each pair of tubes is held in place by a bolted yoke, so that upon loosening the yoke they may be lifted out. This illustration also clearly shows the flat copper tubes, which are placed with their narrow edges facing the air current, as well as the copper radiating fins attached to them. The upper and lower parts of the radiator are hollow castings, which form tanks, the sides merely providing a support and spacer for the tubes. The usual construction consists of a removable tank, which forms the top and bottom

chambers, with a bank of gilled tubes having their ends expanded and soldered into perforated plates, the solder playing an unimportant part, as such joints cannot be relied upon where there is much vibration.

Unless properly provided against, one of the chief sources of injury to the radiator arises out of the twisting of the frame under torsional stresses. Flexible joints between the radiator and motor are accordingly necessary to take care of relative movement, and it is common practice, both in this country and abroad, to employ rubber hose for this purpose. By reason of the heavy loads carried and the use of solid tires, this precaution is not sufficient to guard the radiator against the effects of vibration and road shocks, so that it is usually mounted on some kind of spring suspension. This spring suspension usually consists of a pair of helical springs, one on either side, so that the radiator has no solid connection with its support. In some instances, the radiator is hung on a pair of trunnions, similar to a gun mounting, but this form, while providing ample allowance for movement, does not cushion it against shocks. Still another method consists in mounting the radiator on an extension of the motor, the motor itself being carried on a three-point support, so that the radiator and motor move together; but, unless provided with some form of spring buffer between them, this type suffers from the same disadvantage as the one just mentioned. Figs. 37 and 38 show some typical methods of radiator protection.

Fig. 36. Reo Demountable-Section Gilled-Tube Radiator

Fans. In every case, the radiator is supplemented by a fan driven at high speed, and, in view of the slow travel of the heavier trucks, the proper working of the cooling system depends upon the

efficiency of the fan, since the speed of the vehicle cannot force a strong draft of air through the radiator as it does in a touring car. Thus, the fan is a very important part of the cooling system on a slow-moving vehicle, as it must provide an ample draft, no matter how low the road speed may be, otherwise the engine is liable to heat beyond the point where the oil begins to lose its lubricating qualities. An inefficient fan allows excessive heating every time it is necessary to climb a long hill.

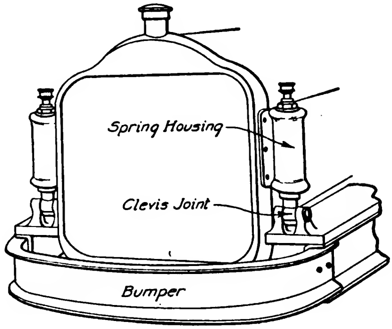


Fig. 37. White Radiator Mounting, Providing Spring Cushioning and Relative Movement through Clevises

Circulating Apparatus. In the majority of cases, the cooling water is circulated by a pump on commercial-car motors, though many heavy trucks, such as the Kelly-Springfield, have thermosiphon circulation. This pump is of the centrifugal type and is capable of delivering a much greater volume of water than are those employed on pleasure-car motors of corresponding power, owing to the reduced road speeds of trucks. These pumps vary more or less in design, but are based almost without exception on the centrifugal principle, as the latter is the only one which will permit of a thermosiphon circulation through it in case the impeller ceases to revolve. A stoppage of the gear type of pump also stops the circulation at once.

Lubrication. Granting that an excess can be prevented from reaching the combustion chambers of the cylinders, it is axiomatic that the power plant of a motor truck cannot have too much oil. In commercial service, the demands upon the lubricating system are quite as severe as they are upon the cooling system, and the failure of one usually involves the failure of the other in a short time. Hence, a greater amount of oil must be provided and every precaution taken to insure its reaching the bearings. Except for the increase in the quantity of

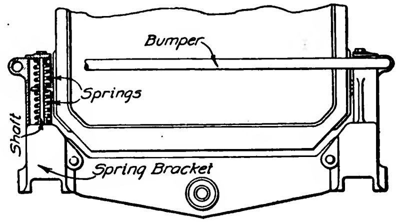


Fig. 38. Spring Hangers Combined with Front Hanger Bracket

lubricant, this does not differ in any way from the requirements of the pleasure car. Consequently, the systems employed are practically the same in both cases. The White lubrication system shown in Fig. 39 illustrates a typical sight-feed system.

Motor Governors

Of the two chief evils that beset the motor truck in the hands of the untrained driver—speeding and overloading—the former is the more destructive, as the driver who will overload his truck will also run at excessive speeds, and, with a heavy load, this is severe punishment for the entire mechanism. The practice became so common in the early days of the motor truck—nearly all drivers

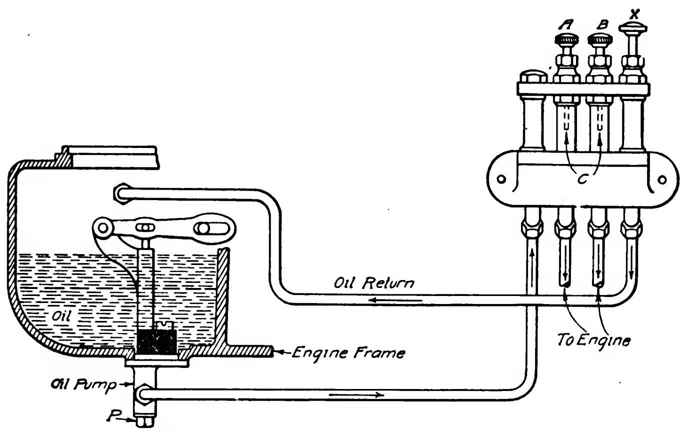


Fig. 39. Sight-Feed (Drop) Lubricating System as Used on White Trucks

then being graduates from the pleasure-car field—that it has now become customary to govern the speed of the motor. The governor itself is usually sealed to prevent its being tampered with by the driver.

General Characteristics. The most generally accepted type is that of the usual centrifugal governor attached directly to the motor and operating a butterfly valve in the intake manifold between the regular carburetor throttle and the valve ports. Owing to the high motor speeds and the slight amount of movement necessary, the governor is very small and compact, so that it will frequently be found incorporated in the crankcase at the end of the camshaft. A variation from this is a drive taken from an outside auxiliary, such as the magneto shaft or water-pump shaft. In either case, the speed of the

governor is always directly proportional to that of the motor itself and bears no relation to that of the vehicle. This is a disadvantage at times, as in pulling through a heavy road on low speed when the maximum power of which the motor is capable is required.

Controlling Car Speed. An improvement on this practice has been the adoption of a vehicle "speed controller" which, while acting on the motor itself in the same manner as the usual motor governor, is controlled directly by the speed of the car and bears no relation to that of the engine. With this type, the motor is free to run at any speed at which the hand-operated throttle will supply it with fuel, so long as the speed of travel does not exceed that for which the governor, or controller, is set. So far as the motor is concerned, it is not directly governed and may be speeded up to any extent necessary to pull the car through heavy going or out of a ditch, as the controller does not come into action while the car is moving slowly. Practically, the only disadvantage of this type is the fact that it does not prevent the motor from racing, as does the former, when the load is suddenly removed, with the throttle open. The vehicle speed controller is driven either from one of the front wheels or from a shaft of the transmission, as its operation depends entirely upon the speed of the car. In addition to the centrifugal method of speed control, the hydraulic principle is also employed. It will be apparent that as the motor speed increases the circulation of the water, as driven by the pump, does likewise, and there is a corresponding rise in pressure in the cooling circulation. This rise in pressure is utilized to act on a large diaphragm connected with a plunger attached to a butterfly valve. A description of some of the governors in use will make clear the method of taking advantage of the different principles of operation.

Centrifugal Type. In Fig. 40 is illustrated a typical centrifugal governor designed for attachment to one of the auxiliary shafts, as will be noted by the driving gears at the bottom. As the revolving weights tend to spread against the compression of the helical spring surrounding the spindle on which they revolve, they push up a yoke to which a shaft directly connected with the throttle valve is attached. As in the case of the steam engine, this valve is entirely independent of the hand-operated valve which may thus be left all the way open. The details of construction of the Pierce governor are shown by

the sectional view, Fig. 41, in which the weights are at the right. As the triangular weights open under the centrifugal force generated, they push the rod forward, and, as this rod has a rack cut on it

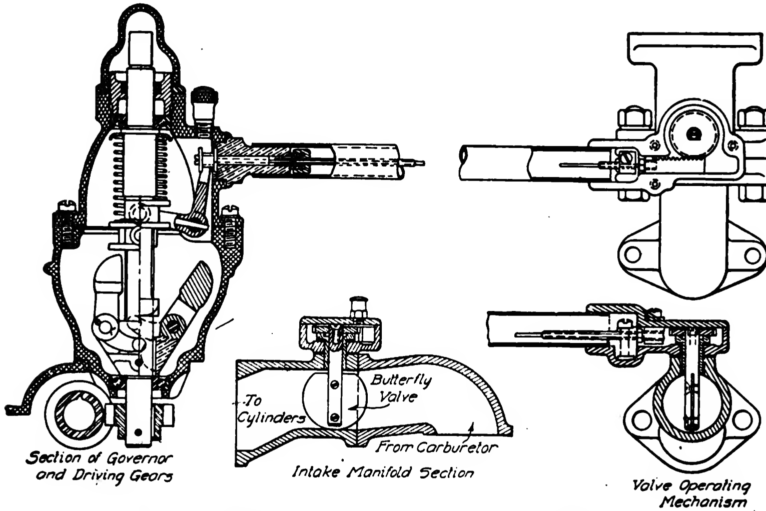


Fig. 40. Sectional Diagrams of Centrifugal Type of Governor

that meshes with a pinion on the butterfly valve, this action tends to close the valve. A spring keeps this rod pressed against the spindle on which the weights are mounted, but is not connected with the spindle in any way. As is true of all governors in this service,

Fig. 41. Sectional View of Pierce Centrifugal Motor Governor

a speed adjustment and a method of sealing it against tampering are provided.

Hydraulic Type. An example of the hydraulic type of governor is shown in section in Fig. 42, while the application of this form of governor is illustrated by the Reo 2-ton truck motor, Fig. 43. As

will be seen in the section, this type consists of a water chamber, diaphragm, spring, and operating lever; the operating mechanism

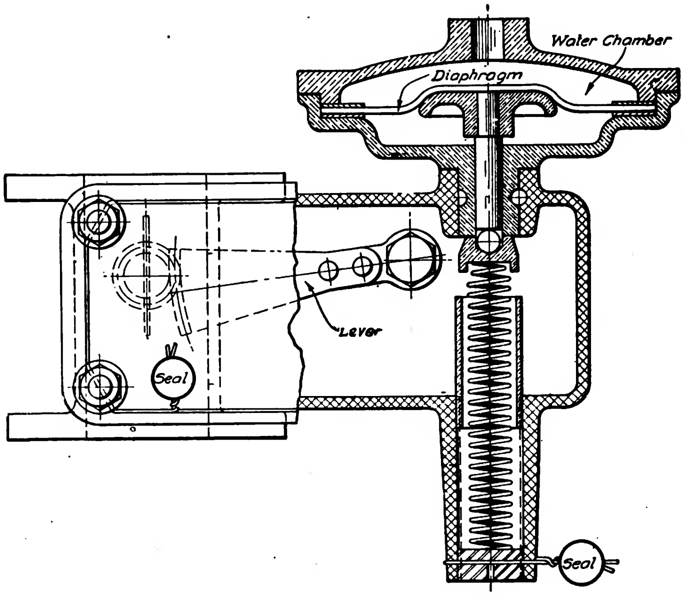


Fig. 42. Hydraulic Type of Governor

being combined with the governor proper results in a simple and compact unit which requires only one connection. This connection is led from the circulating system on the cold-water side, as will be noted in Fig. 43, in order to bring it close to the pump. As the speed of the pump increases, the pressure increases, and the diaphragm is forced down against the spring, carrying with it the lever operating the valve

Fig. 43. Hydraulic Governor as Installed on Reo 2-Ton Truck Motor

through a rack and a pinion. As the pressure decreases, the spring returns the diaphragm, and with it the valve, to its normal position. The water chamber, operating-lever housing, and the spring-retaining plug are sealed so that the adjustment cannot be varied without disturbing one of these seals. In this, as well as in the centrifugal type where the adjustment is effected by altering the tension of a spring, it will be obvious that the spring could readily be screwed up so tightly that no speed of which the motor was capable would have any effect on the governor, thus practically cutting out its action altogether.

POWER TRANSMISSION DETAILS

Clutch and Transmission

Clutches. *Cone Type.* A comparison of the specifications of a number of representative makes of trucks reveals a variation in clutch design about equivalent to what would be found on an equal number of pleasure cars, except that a greater number of instances of the leather-faced cone occur in the trucks. This is the oldest type employed on the automobile and is likewise the simplest in construction, which probably accounts for its more general retention in the commercial field. What is termed the *direct* conical type, in which the leather-faced cone engages by moving forward into the corresponding wedge-shaped recess of the flywheel, is in more general use than the *indirect*, or *internal*, cone in which the male member moves backward into engagement. An example of the latter type is found on the Peerless trucks, while the Garford, Kelly, Vulcan, Mais, and Pierce are representative of the former. In the case of the Pierce, the cone operates in an oil bath, the others running dry, as is more often the case.

Multiple-Disc Type. The Packard and Autocar in this country and the De Dion in France have long been fitted with a three-plate type, the Albion (British) having a single-plate form of clutch in the heavier sizes. Multiple-disc clutches are found on the Locomobile, the Mack, and the Reo, and other American makes.

Transmission. Owing to the great reduction in speed necessary between the motor and the driving wheels, transmission plays a more important part on the commercial vehicle than it does on the pleasure car. On the latter, its services can be dispensed with in an

emergency, as the car can be started on the direct drive in case of accident to the intermediate speeds, but this would manifestly be impossible on a heavily loaded truck. In this connection, it is to be noted that the term "transmission" has come to signify the "change-speed gearset" alone, doubtless owing to the awkwardness of the latter appellation, and does not apply to the transmission of the power from the motor to the rear or front wheels or to all four, as the case may be.

Sliding-Gear Type. In the majority of instances, the sliding-gear type of transmission is employed for commercial work, in which the gears are actually slid into engagement with each other to effect the various ratios of driving and driven members. This type is

Fig. 44. Type of Transmission Employed on White Shaft-Driven Trucks

practically universal on the pleasure car, so that only a brief reference to it is necessary here. On almost all except the lighter vehicles, it provides four forward speeds, the others having but three speeds and reverse. Fig. 44 shows the White transmission as employed with a shaft drive. Owing to the controlling connections being absent, this has been inadvertently photographed with both the first, or lowest speed, and the direct, or highest speed, engaged. The large gear at the left, shown in engagement with its corresponding gear on the layshaft, gives the first speed. By moving it forward until the gear just ahead, with which it is integral, meshes with the next gear to the right on the layshaft, the second speed is obtained. Moving the single gear at the right back until it meshes with the right-hand gear of the pair on the layshaft gives third speed. For fourth speed,

or direct drive, this same gear is moved forward, its forward face being cut in the form of a dog clutch that engages a similar gear permanently attached to the clutchshaft. This is unusual, as the dog clutch is generally formed of a smaller diameter extension on the hub of the direct-drive gear. The two gears at the extreme right-hand end are permanently engaged and serve to drive the layshaft. By moving the largest gear to the extreme left, the reverse is engaged, this being effected through an intermediate pinion, or idler, part of which is just visible below the main shaft at that point. The moving members slide on splines cut on the main shaft, the sliding being sometimes effected by making the main shaft of square section.

Fig. 45. Peerless Transmission and Countershaft

A similar transmission, combined with a bevel drive and spur-gear differential on a jackshaft for side-chain final drive, is that of the Peerless, Fig. 45. This is shown engaged on the direct drive, so the dog clutch is not visible. The material used in the housing is usually aluminum, sometimes cast iron, and, in the case of the Locomobile, manganese bronze. Annular ball bearings are employed in many instances, the bearings themselves being apparent in the White transmission and their mountings in the Peerless. Taper roller bearings are also employed for the same purpose. Operation is almost invariably by the selective method, the gear lever being shifted across through a gate to pick up one or the other of the sliding members shown. The control lever of the White, which is mounted directly on the transmission housing, is shown in Fig. 46. This lever is more often mounted at the side in a fixture also carry-

ing the emergency-brake lever, as on the Pierce. On this truck, only three forward speeds are provided.

Mack Transmission. The Mack transmission, Fig. 47, is a selectively operated type in which the gears of the various speeds are always in mesh, small clutches being designed to slide in either direction on the squared main shaft, engaging the particular speed desired. These clutches are practically small gears which mesh

Fig. 46. Completely Assembled White Transmission, Showing Control Lever

with internal-gear members attached to the driving members. They will be noted lying between the driving gears on the main shaft, in the illustration. The gear housing in this case is of phosphor bronze.

Use of "Dog" Clutches. A variation of the Mack type of transmission employs what are known as "dog" clutches, probably from the fact that they apparently *bite* into one another, being cut with a comparatively small number of heavy teeth on their end faces. These teeth, if they can be properly so-called, are of heavy section

and are cut with an easy angle which insures ready engagement. This will be noted in the direct-drive engagement of the White gearset. The dog-clutch type of gearset has been employed more in Great Britain than in this country. Its great advantages are that the driving gears are constantly in mesh and that the dog clutches can be engaged without particular attention being paid to the speed at which the two shafts are revolving, as is necessary with the sliding-gear type. The details of a transmission of this kind, as well as

Fig. 47. Mack Transmission Used on Manhattan Trucks

of the method of operation, are clearly shown in Fig. 48, which is a Cotta transmission designed for use on worm-driven trucks. As shown in the illustration, the first, or low, speed is engaged, the clutch on the layshaft at the lower right-hand corner being in mesh with its counterpart on the large, or low-speed, gear. The clutch-shaft being at the right-hand end of the gear box, as shown, the drive is then through the pinion on it, the large gear below, with which it is in mesh, and then through the layshaft and the pair of gears at the left-hand end, these gears being fastened to their respective

shafts. The other gears, with the exception of the clutchshaft pinion previously mentioned, are free to rotate on their shafts and are permanently in mesh. However, the male members of the individual clutches, while free to slide on the shafts, must turn with them, so that when engaged they "pick up" the various gears corresponding to the different speeds.

Silent-Chain Transmission. Another form of transmission, which has been used to a greater or less extent abroad, but which has found little favor here, is the silent-chain type. This is along similar lines to the Mack transmission illustrated, except that roller chains take the place of the permanently meshed gears, dog clutches being engaged to pick up the latter according to the speed desired.

Final Drive

Until a few years ago, there was a sharp line of demarcation between the pleasure car and the commercial vehicle where the

Fig. 48. Cotta Individual (Dog) Clutch Transmission Designed for Worm-Driven Trucks

important final drive was concerned. Practically all pleasure cars were shaft-driven, and, to the same extent, commercial cars were chain-driven. The tendency that has manifested itself in the interim makes it apparent that the history made in the development of the pleasure car is apt to repeat itself in commercial-car development. In other words, chain-driven trucks were largely in the majority a few years ago, but the recent advances made in live-axle construction have had a marked effect and their adoption has now reached such a scale that, barring something unforeseen, the chain on the truck will soon disappear as it has from the touring car.

Classification. As at present employed, there are four general classes of final drive on commercial cars. In the order of their age and present comparative importance, these are: first, the double side-chain from a centrally located countershaft carrying the differential and the bevel drive, and usually combined with the gearset, or transmission, so called; second, the worm drive, which differs from the bevel-gear type only by the substitution of a worm and a worm wheel for the bevel gear and the pinion; third, the double-reduction live axle, in which a bevel-gear drive is employed in connection with a second reduction in speed through the spur gears; fourth, the so-called internal-drive rear axle, in which the first reduction is through the conventional bevel gear and the second is by means of a small spur pinion meshing with an internal gear cut on the inner face of a drum attached to the driving wheel. It may occasion some surprise to note in this connection that the worm drive is mentioned as being second in point of seniority, and further that no mention is made of the standard bevel-gear live axle. In the first place, the use of the worm on automobiles dates back to its employment on the Lanchester pleasure cars in 1898 and its adoption on the Dennis busses in London in 1903, on which it has been regularly used ever since. No mention is made of the standard bevel-gear axle here, since the latter is only adapted for use on light cars. The higher speeds at which these vehicles run do not necessitate the employment of extremely high reduction ratios, so that a live axle of this type may be employed without having to make the bevel gear of a size that would seriously reduce road clearance, on the one hand; or a bevel pinion that would exceed the mechanical limitations of this form of drive, on the other. It is rarely employed, however, on vehicles of more than 1½ tons' capacity, and the ease with which the entire speed reduction necessary may be carried out in a single step by means of a worm gear will doubtless make the straight bevel type obsolete on commercial vehicles within the next few years.

Side-Chain Drive. Until the introduction in this country, at a comparatively recent date, of the worm drive, some form of double-reduction gearing has been used on all heavy motor trucks. The form most commonly used has been the double side-chain final drive, in which the primary gear reduction is obtained by means of a bevel gear driving the jackshaft and a secondary reduction in the chains

and sprockets. This type of drive, utilizing roller chains, has been used on nearly all heavy motor trucks since the inception of the commercial vehicle. With but one or two exceptions, on all these trucks of American manufacture no attempt has been made to house the chains in, and they run exposed to dirt, mud, and water.

Standard Types. A typical American side-chain drive for trucks of medium capacity is shown in Fig. 49, which illustrates a Timken unit. Except for the provision of brakes and sprockets at its outer ends instead of wheels, the countershaft, or jackshaft, is practically

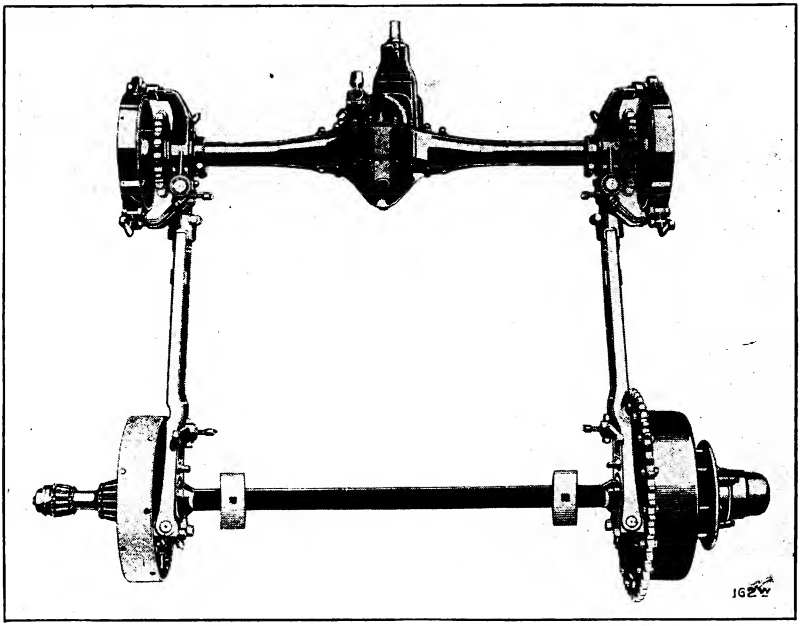


Fig. 49. Timken Standard Jackshaft for Side-Chain Drive

a bevel-gear live axle. The rear axle is what is known as a "dead" axle in that it has no moving parts other than the wheels which revolve on bearings mounted on it. The two wheels are kept at a predetermined distance apart, and their parallelism is preserved by two distance, or radius, rods. A little consideration will make it plain that the thrust of repulsion against the ground of the driving wheels must be taken up on the vehicle before the latter can move, otherwise the rear axle would tend to travel forward independently until checked by the springs, which would then take the driving effort.

This is frequently done on pleasure cars, and makes a flexible power transmission which is easy on the mechansim and the tires, but which is not practical with the heavy loads handled on trucks. Hence, the radius rods are employed to transmit this strain to the frame of the car, but, at the same time, they must provide for a certain amount of relative movement in both a vertical as well as a horizontal plane, besides affording a certain amount of flexibility.

Radius and Torque Rods. Fig. 50, which represents a well-worked-out radius-rod design, illustrates how these various requirements are met. Starting at the right-hand end of the rod which is attached to the rear axle, it will be seen that this design consists of a connecting-rod type of bearing that permits movement in a vertical plane, as this bearing is held on a tubular section of the axle and

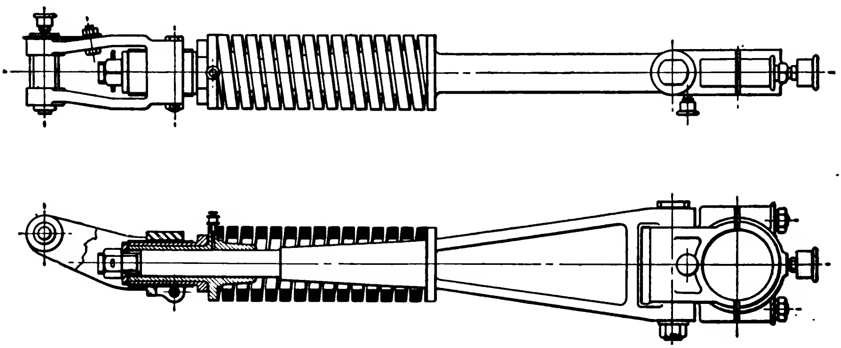


Fig. 50. Flexible Universally Jointed Radius Rod for Double Side-Chain Drive

is kept well lubricated. Just forward of the bearing is a heavy spindle which pivots the rest of the rod on the rear bearing, so that ample provision is made for lateral movement. The rod proper is in two parts held together by the compression of a heavy helical spring, which relieves the mechanism and tires of the initial thrust of starting, and also prevents shocks to the rear axle reaching the frame via the radius rod. Further provision for movement in a vertical plane is made by the attachment of the forward end of the rod to the frame, which forms a pivoted yoke. The threaded portion and the locked collar, noticed at the forward end, allow for adjustment in the length of the rod, this adjustment being provided for in the spring rod by the nut shown inside the yoke at the forward end. On shaft-driven cars, a torque rod is employed to take this thrust and also to take up the twisting effort, or "torque," of the propeller shaft.

Speed Reduction. The rear axle proper is simply a drop forging of I-beam section representing the strongest and lightest cross-section for a beam. It is forged integral with the pads, or saddles, for attaching the springs and is machined to receive the wheel bearings and the bearings of the radius rods which complete its construction. The driving sprockets are bolted to the pressed-steel or cast-steel brake drums and the latter are in turn bolted to the wood artillery wheels. On trucks of two to seven tons' capacity, the speed reduction between the motor and the rear wheels ranges all the way from 7 to 1 to 14 or 15 to 1. The first step in the reduction is carried out in

Fig. 51. Rear of Packard 5-Ton Chassis, Showing Size of Driving Sprockets

the bevel-gear drive of the countershaft and rarely exceeds 4 or 5 to 1, as the use of a larger bevel would involve the use of a cumbersome and weighty housing. The remaining reduction is accomplished by the difference in the driving and driven sprockets. How great this second reduction may be can be seen from Fig. 51, which is a rear view of a standard design of side-chain-driven heavy truck, the Packard. A study of this illustration will make clear several of the details of axle, spring, brake, and radius-rod construction described in previous paragraphs.

Worm Drive. The worm gear was tried tentatively on steam traction engines in England as early as 1850, but it was not until

1898, when it was applied to the driving of the Lanchester car, that it was seriously taken up for this purpose. The Lanchester worm is similar to the more familiar Hindley type except that it is placed under the wheel to insure proper lubrication. Both the worm and wheel are mounted on ball bearings as such a type of bearing is very satisfactory for this load. Worm gears of this tpye are imported from England for use on the Detroit electric cars. The first rear-axle motor-truck drive of the worm type was a 3½-ton Dennis bus

Fig. 52. Phantom View of Pierce Worm-Driven Rear Axle

running in London. This was first put in service in 1903, and, though its introduction met with considerable opposition, it proved a success, and quite a number of worm-driven Dennis busses have been in service in London for several years. Dennis was also the first to mount the worm over the wheel, producing the so-called "overhead" type, which feature also came in for much criticism owing to its alleged failure to provide lubrication. It will be perfectly obvious that with the worm-wheel housing only partly full of oil this criticism would be unfounded, as the wheel acts as an excellent conveyor to carry the oil up to the worm. Eight years' use in London without failure of lubrication bears out this statement.

Development. The London General Omnibus Company was the first to design and manufacture on a large scale a new type of worm-gear axle in which the worm gear was mounted on a separate assembly. This design has superseded others until now, with some modification, it is accepted practice. The worm and the wheel are mounted in a very rigid block and, with their bearings, housings, etc., form a complete unenclosed transmission unit, as seen in Fig. 52, which is a phantom view of the worm gear employed on the

Fig. 53. Chassis of Pierce 5-Ton Worm-Driven Truck

Pierce trucks, the makers of the latter having been the pioneers in introducing this type into the United States. This unit is dropped into the bowl-shaped rear-axle housing and bolted in place. This mounting lends itself readily to accurate machining, every part being open and easily accessible. This is also true of the unit as a whole where inspection, adjustment, and repair are concerned. This housing is of heavy construction and, as it is rigid, prevents road shocks or stresses, other than those coming through the driving

axles, from disturbing the alignment of the worm gear. The housings of the driving shafts, or axles, are tubular, and the shafts themselves are assembled through the tubes into the squared sockets in the differential. This makes a very accessible assembly as, by pulling out the driving axles and disconnecting the universal joint, the worm unit can be lifted out of its housing. The socket, with several keyways in it extending forward from the worm proper, is for the reception of the splined end of the propeller shaft from the gearset. This keyed socket is the slip end of the rear universal joint in the shaft line and is designed to prevent relative movement of rear axle and of gear set from imposing excessive stresses on the propeller shaft.

The driving thrust and the torque are taken on a short heavy torque rod, which will be noted extending forward from the rear-axle housing just below the universal joint. This is a heavy drop forging and, as will be clear, is mounted on a heavy spindle at the axle housing, allowing for movement in a horizontal plane; while at its forward end, which is made in the form of a yoke, it is carried on a horizontal pin permitting a vertical movement to compensate for variations in the vertical distance between the axle and frame caused by the compression and recoil of the springs. Its location is made clear in the chassis view, Fig. 53.

Fig. 54 shows the form of mounting adopted by the Timken Company for the David Brown type of worm drive which they manufacture. This is the same as that employed on the Pierce trucks, but both the method of mounting and the bearings differ. The Timken Company use their own taper roller bearings, while the Pierce Company use annular ball bearings. The worm is of the so-called straight type, meaning that it is of uniform diameter throughout its length as distinguished from the "hourglass" type.

Standard Types of Worm Gears. In the straight type, the worm is cylindrical through its entire length, and the worm wheel into which it meshes is concave. In the hourglass type, both worm and worm wheel are concave. The advantage claimed for the latter form is the greater area of engagement, thus spreading the driving strain over a greater number of teeth and reducing the pressure on the surface of both. On this type, however, there is only one position in which the worm and the worm wheel can be located with respect to each other in order to take advantage of this greater area of con-

tact, while on the straight type it is necessary only to locate the worm correctly, with respect to the worm wheel, in one direction, since the worm is cylindrical and uniform in diameter throughout its entire length. The straight type is therefore much less liable to damage through misalignment. With the hourglass type, a slight misplacement in any direction is liable to prove fatal, so that the chances of trouble in practical operation are greatly reduced in the straight type.

Efficiency of Worm Gears. In an elaborate test of three different types of worm gears (by types in this connection being meant

Fig. 54. David Brown Type of Worm Gear as Mounted on Timken Axle

differences in tooth form and pitch) made at the Brown and Sharpe plant to determine which form was best adapted to automobile use, efficiencies ranging from 90.2 to 95.5 were obtained on the first speed, 91.3 to 93.4 per cent on the second speed, and 90.1 to 97.6 per cent on the direct drive. The results obtained with a bevel-gear-drive test made for comparison were 91.4 to 96.6 per cent on first speed, 94.5 to 99.3 on second, and 94.0 to 99.2 on direct drive. So far as the life of the worm is concerned, mileage records obtained on commercial cars range from 40,000 to 110,000 miles, the lower figure

being considered only fair for a well-made straight type of worm; while, on pleasure cars, three years of constant service was not thought at all unusual.

Double-Reduction Live Axle. As sufficient drop in speed cannot be had with a bevel gear through a single reduction without making the driven bevel gear of impracticable proportions, thus involving excessive weight in the rear-axle housing and a dangerous lack of clearance between the latter and the ground, an intermediate spur reduction is introduced just forward of the bevel gears. One method of accomplishing this is illustrated by Fig. 55, which shows the extra speed reduction combined in the same housing as the differential and the bevel drive, an extra cover plate making it accessible. It will be noted that helical-cut gears are employed

Fig. 55. White Differential, Showing Second-Reduction Gear

instead of the straight-spur type, this form of tooth giving greater bearing surface, closer engagement, i.e., less backlash, or lost motion, between the gears and far less noise in running. Another form of double-reduction axle is the special type developed on the Autocar delivery wagon and illustrated in connection with the description of that vehicle.

Internal Gear-Driven Axle. The internal gear-driven type of axle is another form of final drive that has been introduced in this country after a long and successful record abroad. Like the worm gear, it aspires to the honor of replacing the side chains and, like that form, also has already made considerable progress in this direction. In principle, this form of drive consists of making the driving axles independent of, and external to, the rear axle proper, which, in this case,

is of the "dead" type, usually a solid section, such as a square or an I-beam forging. Its function is merely to carry the weight of the car, although it also is made to serve both as a support and as a reinforcement for the live axle. In the case of the Mercedes (German) trucks, on which it has been used since 1900, the driving axle is placed forward of the dead axle. At their outer ends, the shafts of the former carry small spur pinions which mesh with large internal gears cut on rings attached to drums on the rear wheels. One of these wheels and the driving pinion on the end of the live shaft are illustrated in Fig. 56, which shows this construction as carried out on an American-built replica of the German truck in question.

This same form of axle has been employed also for a number of years in Paris by the builders of the De Dion cars for their commercial types, chiefly busses. In this case, the live axle is carried above

Fig. 56. Mercedes (German) Internal Gear Drive, Showing Principle of Action and Assembled Rear Wheel

its support. More than a hundred of these busses have been in service in New York for several years and, as more are ordered from time to time to meet the increasing requirements, it must be concluded that they have been satisfactory. The builders of the Mais trucks were doubtless the pioneers in the commercial use of this form of axle in this country, and the Mais internal gear-driven rear axle is probably the form in which this type is most generally used. In this case, the driving axle is placed forward of the dead axle. Upon comparing the size of the driving pinion at the rear wheel with the internal gear, it will be apparent that a very large gear reduction is conveniently obtainable by this method without in any way interfering with the road clearance of the vehicle. The first reduction consists, of course, in every case, of the conventional bevel-gear drive, but, as will be noted from the part sectional views of the Torbensen and Garford

types of internal gear-driven axles, as shown in Figs. 57 and 58, there is very little reduction between the bevel pinion and its gear. This decreases the amount of leverage the pinion has to exert and conse-

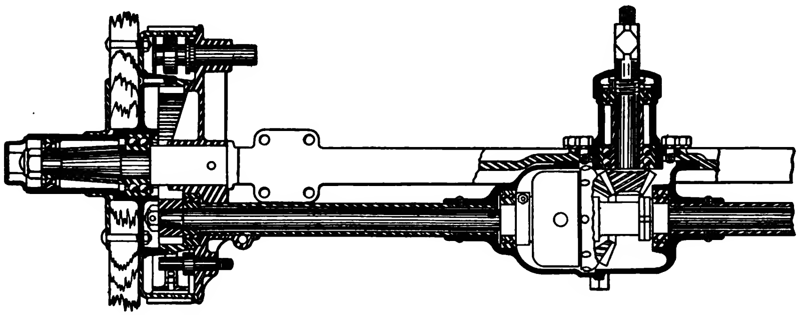


Fig. 57. Torbensen Internal Gear-Driven Rear Axle

quently decreases the tooth pressure in proportion. In the Torbensen axle, the live member, or countershaft, is placed to the rear of the I-beam supporting member, while in the Garford this is reversed. On the Jeffery "Quad", it is placed directly over the wheel support, as

Fig. 58. Garford Internal Gear-Driven Rear Axle

shown by Fig. 59, which illustrates the driving pinion and the wheel with its internal gear. As this truck steers, drives, and brakes on all four wheels, a universal joint is placed directly behind the pinion. Fig. 60 shows the wheel and its gear ready for mounting. A some-

what similar design is found on the Christie front-drive tractor for fire apparatus, with the added distinction that on this machine only the rim of the driving wheel revolves and is carried on a ball bearing which is practically the size of the wheel itself. On the Jeffery, the wheel revolves on the two taper roller bearings shown.

Differential Lock. The function of the differential, balance gear, or compensating gear, as it is variously called, is naturally the same on the commercial vehicle as it is on the pleasure car, i.e., that of permitting one wheel to run free in rounding a turn so that it may travel the greater distance represented by the outside circle in the same time that the inner takes to traverse its orbit; but the differential has the unfortunate drawback of not permitting any power to reach one of the driving wheels in case it is held while the other is free. This frequently occurs where the truck settles into a ditch or extra deep rut in a soft road, leaving the other wheel more or less in the air. Under such conditions the entire power goes to the free wheel, making the problem of extricating the machine from this predicament much more difficult. To overcome this disadvantage of the balance gear, it is customary to provide a differential lock. One form of this lock is illustrated in Fig. 61. On the right-hand side a four-jaw clutch is keyed to the drive shaft, but is left free to slide into mesh with its corresponding member on the differential housing to permit of locking the differential gears. This clutch is operated through a suitable linkage from the driver's seat. By locking the differential, the sunken wheel will pull itself out if the truck is capable of exerting the necessary power.

Fig. 59. Jeffery Rear-Axle Driving Mechanism and Bearings

Front Drives. *Early Development.* One of the earliest applications of power proposed for road locomotion was the attachment of a self-contained power unit to existing horse-drawn vehicles, and a number of different types of such units were built in Europe in the early days of the industry. For some reason, none of them developed to the point of a commercial success. The front-wheel drive, which seems to have been discarded almost entirely for some years, has recently come to the fore again and has been developed very successfully for fire apparatus, on which both mechanical and electrical methods of transmission have been utilized.

Fig. 60. Jeffery Wheel with Internal Gear Ready for Mounting on Axle

Electric Front Drive. The electric front drive has been utilized in numerous lines of business, more particularly for brewery and municipal service, for several years; the Couple-Gear type of electric motor wheel, previously described in the section on the transmission of power on electric cars, was employed for this purpose. In some instances, a single power wheel is used to haul a dump cart or similar slow-moving vehicle; or a unit, comprising a storage battery, controller, steering gear, axle, and two of these power wheels, is permanently coupled to a truck in place of the axle and wheels used when drawn by horses.

The power to drive these motors may be supplied by the current from a storage battery or from a gasoline-electric generator. The

Fig. 61. Bevel-Driven Commercial-Car Axle Fitted with Differential Lock

Fig. 62. Electric Front Drive Using Couple-Gear Motor Wheels

dynamo supplies the power directly to the wheel motors through a three-point controller, there being no other intermediate electric

member. This controller is fitted with two forward speeds and a single reverse, the speed and amount of power utilized being controlled chiefly by means of the spark lever and the throttle of the gasoline motor in the conventional manner. Fig. 62 illustrates a fire engine gasoline-electric tractor using Couple-Gear drive.

Four-Wheel Drives. To meet the requirements of military service, a truck must be able to travel "wherever a team of mules can haul a load". Consequently, like that useful quadruped, it must be equipped with power-transmitting members at all four points of contact with the ground. While the conventional type of truck with one or the other of the standard forms of transmission driving only two rear wheels has proved eminently satisfactory for service wherever a solid roadbed or its equivalent is to be found, it is of little use off the beaten track. Ditches, soft ground, sand, and mud, which do not even embarrass the army mule or, for that matter, the average team of farm horses, render the average motor truck absolutely helpless. To be able to extricate itself from bogs and ditches, it is necessary to be able to "git up and git" on all fours.

To take advantage to the full extent of this form of transmission, the majority of four-wheel-driven cars both drive and steer through all the wheels. Accomplishing this presents no particular mechanical difficulties. Three forms of drive have been developed for this purpose; one in which the power is transmitted through bevel gears mounted on the steering knuckle,while a second employs the internal-gear type of drive using universal joints on the driving shafts just back of the wheels. The third type drives directly to the hubs of the wheels through hollow steering knuckles. This last type presents the simplest layout and was one of the first to be developed in this country on a commercial scale, having been built for several years by the Four Wheel Drive Automobile Company.

This transmission is a simple modification of the three-speed individual-clutch type transmitting the power through a broad silent chain to a parallel shaft placed at the left to clear the engine. This can be seen more clearly in the photograph of the chassis, Fig. 63. This chain also serves as the first reduction in the speed, the second being through the conventional form of bevel gears at the rear and front axles. Each of these bevel-gear drives incorporates a differential for balancing the tractive effort at the wheels, while a third

differential centrally placed on the parallel driving shaft balances the amount of power transmitted to each pair of wheels. This third differential is built in the large sprocket of the silent-chain drive and is provided with a locking device controlled by the driver. A brake

Fig. 63. Chassis of Four-Wheel Drive Truck

drum is mounted on the parallel shaft on either side of the main differential. These transmission brakes are for regular service, the emergency brakes being mounted in drums on the rear wheels.

Fig. 64. Chassis of Jeffery "Quad", Showing Four-Wheel Drive

Owing to their location, the former retard all four wheels simultaneously. There are, of course, four universal joints. Steering is accomplished by means of the front wheels only, so that the rear axle is of the conventional full-floating construction.

Jeffery "Quad". This truck is representative of the second class, or internal gear-driven type mentioned, and has been developed particularly to meet the United States Army requirements. The motor is a four-cylinder block-cast type with L-head cylinders rated at 32 horsepower and is fitted with duplex ignition, i.e., using

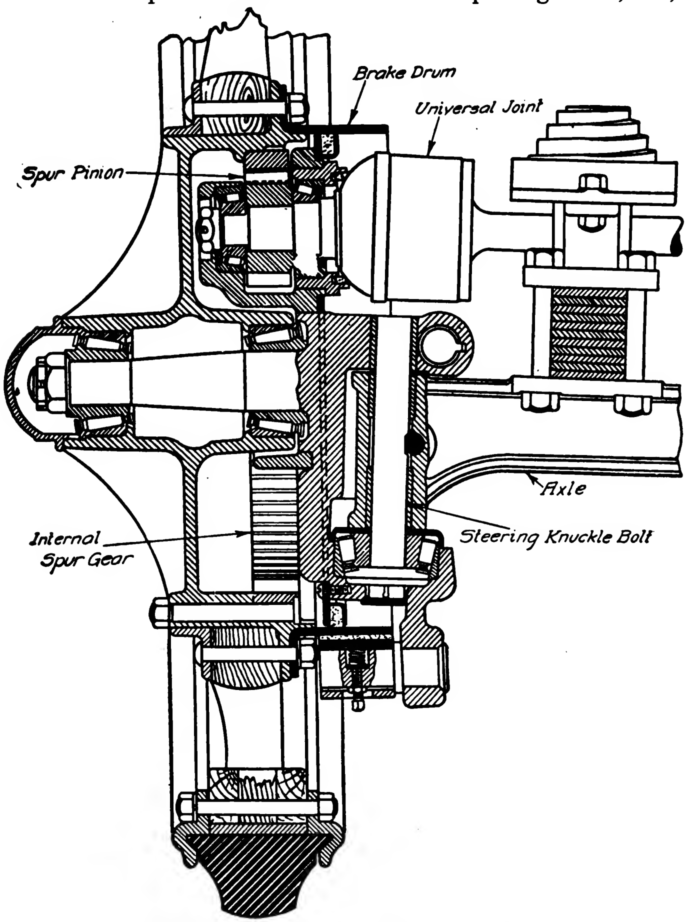


Fig. 65. Sectional View of Jeffery Front-Wheel Drive
Courtesy of Horseless Age

two sets of spark plugs simultaneously. The motor is offset to the right side of the frame and mounted on a three-point suspension, as shown by the plan view of the chassis, Fig. 64. The drive is by shaft to a centrally placed four-speed selectively operated gearset of the sliding-gear type, but the latter differs from the conventional

form of this type of gearset in that it has no direct drive. The propeller shafts are gear driven from the layshaft of the transmission, this construction bringing the forward one sufficiently to one side to clear the motor. Three differentials are employed, one on each axle and one in the gear box, all being of the Wayne gearless type. Both axles are "dead" and are fitted with steering knuckles. The transverse driving shafts at either end are placed above the axles and springs and have universal joints just inside of the wheels and directly over their steering pivots, as shown by the sectional view, Fig. 65. The driving pinion is supported from the steering knuckles between two taper roller bearings and drives an internal gear mounted in the enlarged wheel hub. Bolted to this large hub and the wheel itself is

Fig. 66. Chassis of Jeffery "Quad"

a pressed-steel drum for an external brake, a dust-excluding felt packing being fitted between the drum and the gear ring. The ability of the four-wheel drive to extricate itself from heavy mud and sand with the same amount of power is due to the tendency of the front wheels to climb over obstacles and, at the same time, assist in the propulsion of the weight. Enclosed wheels are employed to cut down the resistance, Fig. 66.

Electric Transmission

Advantages. The practice of utilizing electricity for power distribution in manufacturing plants was already well established before the advent of the automobile on a commercial scale, and attempts were made at an early day to utilize its advantages for transmitting

the power on the latter. Despite the numerous difficulties met with at the outset in the application of the sliding-gear transmission, the employment of electricity has never become as general as its advantages would appear to warrant. A great amount of experimental work, however, has been done, and numerous different systems evolved. Probably the only example of the consistent employment of electric transmission at the present date is to be found in its use on gasoline-electric-railway motor cars, of which quite a number are in service. As the limitation of weight, one of the most important factors to be considered on the automobile, is lacking in this application, it can hardly be said to represent an exact parallel.

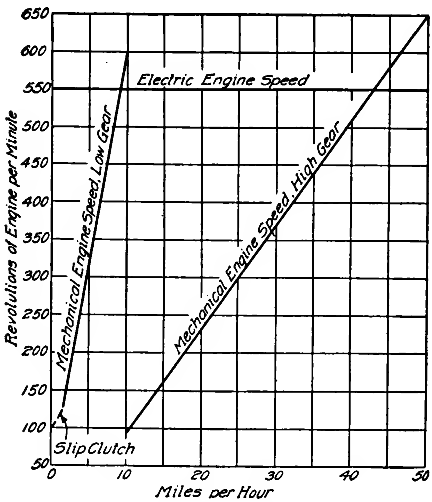


Fig. 67. Curves Showing Variations of Engine Speed for Gasoline-Electric Transmission

One of the chief advantages of the employment of electric transmission is the possibility of running the gasoline motor constantly at its normal speed, at which it develops its rated output most economically and with a minimum wear. The sharp contrast between the speed variations required of the gasoline motor employed with a mechanical transmission and with one of the electrical type is shown by the curves in Fig. 67. With the electric transmission, the gasoline motor speed remains constant from the time of starting right up to 50 miles an hour.

Several Systems. To those familar with electric practice it will be plain that several methods of utilizing electricity for the transmission of the power on an automobile are available. In general, however, they may be divided roughly into three divisions. The first of these is simply a replica of that commonly employed in manufacturing plants, i.e., mechanical energy as produced by an engine is converted into electrical power, transmitted to an electric motor at a distance, and there reconverted into mechanical energy. This

double conversion naturally entails a loss of efficiency; but, in manufacturing practice, this is considerably less than where the power is directly transmitted from the engine to the tool at which it is to be used, and the efficiency increases with an increase in the distance between the two.

The second system involves the conversion of mechanical into chemical energy in the storage battery, from which the current is drawn to operate electric motors in the usual way, Fig. 68. This is really a self-contained electric in that it carries its own charging plant, with the further advantage, however, that the excess capacity of the generator is always available for driving the vehicle. Or, to put it

Fig. 68. Couple-Gear Gasoline-Electric System

the other way around, the greater part of the current from the gasoline motor electric-generator unit is employed for running the car, and the excess current utilized for charging the storage battery, which is then said to be "floated on the line."

The third system is based on the principle employed in the cradle type of electric dynamometer, in which an electric generator is so mounted that its field may revolve in response to the drag exerted on it by the armature, this tendency being counteracted by a balance lever attached to the field. By means of weights placed on this lever, the effort exerted may be accurately weighed, and the power developed by the prime mover driving the generator may be calculated within close limits.

DETAILS OF CHASSIS AND RUNNING GEAR

Springs

The problem of providing a form of spring suspension that will not be overstiff when the car is empty and still provide sufficient holding powers to withstand rough road work with a full load, which the designer of the touring car has had to face, is aggravated a hundredfold on heavy trucks. Between the "load" and "no load" points of the pleasure car, there is a comparatively small range. When a touring car weighing 4000 pounds, all on, has its full load of seven passengers averaging 150 pounds each, their combined weight represents only 25 per cent of the weight of the vehicle itself, but when a 5-ton truck, weighing slightly over five tons when empty—say 11,000 pounds—receives its full load of five tons plus anywhere from 10,000 to 14,000 pounds, the increase, instead of being from 0 to 25 per cent, is from 0 to 100 per cent plus. There is also the far greater tendency to side sway, owing to the height at which the load is ordinarily carried.

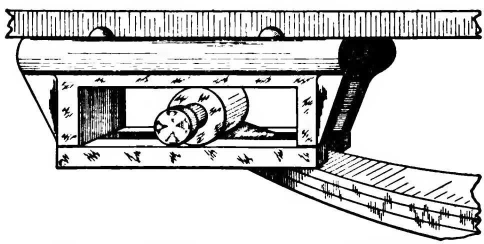


Fig. 69. Principle of the Compensating Spring Support Employed on Heavy Trucks

Semi-Elliptic Usual Type. As it permits keeping the center of gravity down, gives less recoil under heavy shock, and is less subject to lateral stresses, the flat semi-elliptic type of spring is almost universally employed on commercial vehicles, from a delivery wagon up to a 7-ton truck. By delivery wagon in this connection is meant the type specially designed for commercial service and not the converted touring-car type in which pleasure-car standards remain unaltered, and the high three-quarter elliptic spring at the rear is not uncommon.

It will be apparent, however, that no form of spring suspension would be sufficient in itself to cover such an extended range of loading as that mentioned and still give even a fair approximation to efficiency at either extreme. Maximum carrying ability is the chief thing to be provided, and using springs that will do this alone would be an easy matter; but the problem is to guard against the maximum

stresses to which the springs will be subjected under heavy loads and still have a suspension that will prevent the motor and driving mechanism of the truck from being pounded to pieces when the vehicle is running without a load. To achieve this, it is customary to employ rocking shackles at one end and some form of sliding, or compensating, support at the other, although in numerous instances the springs are shackled at both ends in the same manner. As the driving strain is practically always taken on radius, or distance, rods in the case of side-chain-driven cars, and on torque rods on cars of the shaft-driven type, there is ample altitude for variation in this respect.

Principle of Compensating Support. The sketch, Fig. 69, illustrates the principle upon which all compensating supports for the springs is based. Of course, this applies only to the rear-wheel springs, which are usually called upon to bear anywhere from 60 to 85 per cent of the useful load. The front springs are usually pinned to the dropped dumb ends of the frame forward and shackled to brackets at their rear ends. The front end of a rear spring is shown by the illustration. Given a suspension sufficiently stiff to withstand the maximum load of which the truck is capable, it will be apparent that when empty the body will be lifted and the sliding end of the spring will be against the right-hand end of the support. The spring is then under its minimum compression and will respond more readily to shock.

Brakes

Usual Types. In as much as the greater loads carried far more than offset the lower speeds at which commercial cars travel as compared with the pleasure type, there can be no comparison of the braking requirements of the two. This is particularly the case in as much as the greatest strain does not come on the brakes because of the infrequent necessity for stopping suddenly but on account of their continued use in holding the loaded truck back on long hills. Commercial-car brake design naturally varies with the type of vehicle and likewise with its carrying capacity. On light delivery wagons, the type employed is the same as used on touring cars, viz, internal-expanding and external-contracting asbestos-fabric-lined shoes in pressed-steel drums on the rear wheels. In some instances, the practice, usually confined to the higher-priced pleasure cars, of placing the two sets of brakes side by side so that they contact on the same

drum and can be enclosed against the entry of dirt and water, is also found. An example of the first type mentioned is shown in Fig. 70, which illustrates a Timken worm-driven rear axle. The brakes on the Reo chassis are shown in Fig. 71.

Braking All Wheels. Considerable discussion has arisen from time to time regarding the advisability of braking on all four wheels;

Fig. 70. Timken Worm-Driven Rear Axle, Showing Brakes

but, prior to the advent of the four-wheel drive, this was tried in only a comparatively few instances. In addition to providing greater retarding power, the advantage of eliminating the tendency to skid has also been attributed to the front-wheel brake. When all four

Fig. 71. Brake Detail, Reo 2-Ton Chassis

wheels are driven, brakes are applied to all simultaneously, the braking effort at each wheel being equalized by a compensating device. On the Jeffery "Quad", these brakes are applied directly to the wheels themselves and consist of a simple and well-worked-out internal-expanding cam-actuated type, as shown by Fig. 72.

TRAILERS

Utilizing Excess Power. Trucks, like all other motor vehicles, must necessarily be equipped with power plants capable of successfully meeting exceptionally severe conditions imposed by heavy grades and by muddy, sandy, and snowy road surfaces, as well as the normally easy grade and road conditions encountered by the average truck during a very large proportion of its service. Hence, there is a large reserve power-plant capacity idle for a great part of the time. From the economic standpoint, it is a wasteful condition for a truck with sufficient power to handle a ten-ton load on smooth

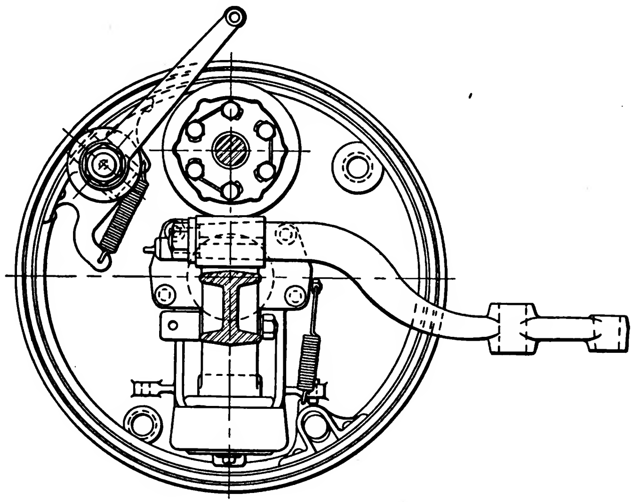


Fig. 72. Internal Expanding Cam-Actuated Type of Brake Employed on the Jeffery "Quad"

level roads to be restricted to the five-ton load which its structural parts permit. This applies proportionately to all sizes of commercial vehicles, from the very lightest up, and it accounts for the widespread use to which trailers are being put.

Two-Wheel Types. For light- and medium-capacity service, trailers can be made with only two wheels, thus keeping the wheelbase of the double unit down and permitting of much higher speeds. Trailers designed for use in connection with the lightest types of delivery wagons, such as the Ford, or for the thousands of ex-touring cars that are spending the second period of their existence in a commercial rôle, usually carry a load of about 400 pounds. They are

made to fit any standard make of automobile, a special bracket being fitted to the rear of the frame of the car. Connection is made by means of a tongue fitted with a swiveling pin and locked with a thumb nut, so that the trailer may be attached or detached quickly without using tools; the pin in question, together with the fact that the trailer has only a single axle, allows for universal relative movement between it and the towing car.

Four-Wheel Types. It is in the employment of what is practically a second truck, where its carrying capacity is concerned, that the use of the trailer shows the greatest operating economy, and

Fig. 73. Troy Trailer for Motor Trucks

specially designed vehicles have been developed for this purpose. The builders of the Troy wagons have evolved a special type of trailer for the motor truck, as shown in Fig. 73.

Troy Trailer. It will be noted upon referring to the illustration, Fig. 73, previously mentioned, that the construction of the Troy trailer is along very similar lines to those generally followed in motor-truck construction. In fact, the trailer is practically a motor truck without power and, as it is subjected to even heavier loading and more severe strains than the latter, is built accordingly.

Both sets of wheels are designed to steer and are controlled by the drawbars at each end of the trailer, the cross-connecting rod of

the steering gear being attached to the under side of the drawbar near its rear end. As the drawbar follows its towing truck around corners, it also serves to swerve the front wheels of the trailer in the same direction.

RAULANG ELECTRIC COACH

Courtesy of The Baker R. and L. Company, Cleveland, Ohio

ELECTRIC AUTOMOBILES

Introduction. The essentials of the electric automobile are few in number and simple in construction. They are, first, the storage battery, or source of power; second, the electric motor, forming the medium through which the current is transformed into mechanical energy; and, third, the drive, or means by which the power of the motor is in turn applied to the propulsion of the vehicle. There are, naturally, differences in design and in the details by which the power produced at the electrical end is applied to driving the machine. Where these differences are of sufficient importance, they are described in detail, and illustrations of the vehicles and their component parts are given, thus enabling the reader to very easily distinguish between these units and between their methods of operation.

FUNDAMENTAL FEATURES OF THE ELECTRIC

THE STORAGE BATTERY

There is probably no other single electrical device in general use about which there is so much popular misconception as the storage battery, or accumulator, as it is more technically known. It does not in itself create a current of electricity—as does a primary battery, such as the familiar dry cell, in which chemical processes actually generate a current of electricity—and for this reason the storage cell is called a secondary battery. The word *storage* in connection with this type is really a misnomer, as the process by which it absorbs and re-delivers electricity is not one of storage in any sense of the word, but consists of chemical conversion and reconversion upon a reversal of the conditions. As is the case with electric vehicles, there are numerous different forms of storage batteries, for many of which special advantages are claimed; but in general all lead-plate batteries are alike in principle and are completely described in the Electrical Equipment section of this set of books. Theoretically, the principle of the Edison battery is also the same, i.e., that of a chemical reaction upon the passage of the charging current.

THE MOTOR

Quite in contrast with that of the gasoline car, the motor of an electric vehicle is probably responsible for less of the troubles encountered than any other one of the essential components. While the relative amount of attention it requires at the hands of the owner of the vehicle is small, a knowledge of its construction and working will be found of value in the operation and maintenance of the car. It is here that the energy held in reserve in the storage battery is converted into the mechanical power necessary to move the vehicle. The reason for the small amount of attention required is apparent in the small number of parts as well as their great simplicity, though the great amount of attention that has been devoted to the development of the electric motor over a long period of years is largely responsible for the elimination of the numerous shortcomings of the earlier types.

Essentials of Motor. The motor consists of a *field*, an *armature* suitably mounted on bearings so that it may be revolved in that field, a *frame*, a *commutator*, and *brushes*. The term *field* is the generally accepted abbreviation for magnetic field, which is the zone of influence exerted by a magnet, and is referred to in terms of its "lines of force". A common horseshoe magnet, technically known as a *permanent magnet*, will attract to its ends or poles particles of iron and steel placed within a certain distance of it. The space bounded by the poles of the magnet and the limits to which its attraction reaches, is known as its *field*. With reference to electric motors and generators, the word is employed to designate the magnets and pole pieces which serve to create this field, rather than the scope of magnetic attraction itself, and it is used to embrace all of them, regardless of their number.

Principle of Rotation. The fundamental principle upon which the functioning of all apparatus of this type is based is to be found in the fact that when a current of electricity is passed through a coil of wire surrounding a bar or other form of iron or steel, the metal becomes magnetic in proportion to the number of turns in the coil of wire and the strength of the current employed. Every magnet consists of a north and a south pole, and *like poles repel while unlike poles attract one another*. In other words, if two small common mag-

nets are placed on a table with their like poles, i.e., north to north and south to south, facing one another, the magnets as a whole will tend to repel one another, and were they sufficiently powerful, would actually recede from the common center until the limits of their field were reached. By reversing the polarity of the opposing ends of the magnets, they would then tend to be drawn to one another until the poles butted. This, in brief, sums up the philosophy of the electric motor.

In order to amplify the power, a large number of magnets are employed; and in order that the energy thus developed may be utilized, one group of magnets is made stationary while the other group is free to revolve. In these two groups will be recognized respectively the field and the armature of the motor, and each magnet of the groups is of the type known as *electromagnets*, so termed because they are magnetic only while a current is passing through their exciting coils. Those of the field may be distinguished as they take the form of short thick spokes radiating from the rim or frame toward the center. They thus surround the space in which the armature revolves, and are further provided with what are known as *pole pieces* in order to fill as much of the space with iron as is possible. As already mentioned, the field of a magnet is most powerful in close proximity to it and the armature will be seen to run as closely to the faces of the pole pieces as good design and construction will permit.

Now it will be remembered that the direction in which the current of electricity is sent through the exciting coil determines the polarity of the resulting magnet. If, with the current traveling round the coil in one direction, the right-hand end of a bar becomes of north polarity and the left-hand end of south polarity, it will be evident that, by reversing the direction of current flow, there will be a corresponding change in the location of the poles. Coming back to practice, in which one set of magnets—the field—is held stationary, while the other may revolve, it will be apparent that as each of the armature magnets approaches a field magnet by virtue of the attraction between them, the motion will tend to accelerate up to the point where they are opposite, but when the moving magnet passes by, the attraction which still exists will tend to stop the rotation. It is clear, therefore, that, to bring about the desired rotation of the armature some device must be used to reverse the direction of the current

in each electromagnet when it has reached a point opposite the field magnet which is attracting it so that the resulting *opposite polarity* may develop a repulsion which will carry the armature in the same direction. This is just where the function of the commutator and the brushes comes in. The brushes serve to lead the current to the circular group of copper bars which forms the commutator, without retarding the rotation of the armature. Each section of the commutator is insulated from its neighbors and as the brushes touch opposite sections simultaneously the rotation makes the current enter the armature coils first in one and then in the opposite direction, through successive sections of the commutator, the current being reversed and the polarity of the field magnets being changed for each new position.

The Armature. The foundation of the armature consists of a cylinder built up of laminations of iron, or punchings, with recesses cut into their circumferences to receive the coils of wire, or windings, each one of which converts the particular section of the core that it surrounds into a powerful electromagnet when the current is passing. All the wire employed is strongly insulated, not only to protect neighboring turns from one another, but each winding is also well insulated from its foundation, whether this be the armature or a field core. If this precaution were not taken, *short circuits* or *grounds* would occur. The former term is really self-defining as it shows that the current instead of passing round the entire coil or circuit intended, would choose the shorter path thus accidentally provided. A ground, on the other hand, is caused where non-insulated portions of two different wires carrying a current come in contact with the same or a connecting piece of metal, or other conducting medium. This opens up a path of practically zero resistance for the current, thus diverting it entirely from the path it should follow if its energy were to be utilized.

Both short circuits and grounds are things with which the owner of the electric vehicle will have to become familiar to a greater or less extent in caring for the battery of his car, as well as the remainder of its electrical equipment, so that their nature has been explained in detail. While both cause similar results, they are not interchangeable terms and are employed to convey the distinction mentioned. In other words, a ground may be a short circuit, but a short circuit

is not always a ground, as the latter implies the diversion of the current through some normally unused conducting medium, while the short-circuit signifies a breakdown of the insulation of the wiring or allied appurtenances that permits of the return of the current after having traversed but a fraction of the path intended for it. Either trouble naturally places the piece of apparatus in which the break occurs out of running order until the defect is remedied. In view of their nature, grounds are usually much more difficult to locate than short-circuits. Some of their further causes and results are mentioned in the chapter devoted to the care of the batteries, also that on the wiring.

Capacity for Overloads. It is this capacity of the motor to stand excessive overloads that fits in with the requirements of the road, for it must be borne in mind that the amount of power required to keep a vehicle rolling after it is once started is very small as compared with the pull necessary to start it, or to accelerate its speed. The total amount of energy required is in direct proportion to the total weight, and to the square of the velocity.

Motor Stands 500 Per Cent Overload. The pull, or *torque* of the motor as it is called, must be very heavy at starting, particularly when on an upgrade, and also for mounting inclines. For this reason, the motor employed is of a type capable of standing for short periods as much as 500 per cent in excess of its normal rated capacity. It will be apparent that this converts the 2½-horsepower motor into one of 12½ horsepower in cases of emergency, but it increases its current consumption under the ordinary conditions of load at which the greater part of its service is rendered, such as in running on the level or ascending ordinary inclines. The available amount of power being so closely restricted by the capacity of the battery, it will be manifest that this is a most important provision, and as the average layman talks in terms of horsepower without adequately comprehending the meaning of the latter, electric vehicle makers have found it expedient to omit any mention of this factor. The electric not only is not intended to be capable of the speeds of the gasoline car, but it does not require such an excessive amount of reserve power as it has become customary for the manufacturer to provide on the latter type.

Under usual conditions of running, the average gasoline machine

does not employ more than a small fraction of the available power of its motor and, in consequence, is seldom being operated at what is technically termed its *critical speed,* that is, the speed at which it is most efficient, and therefore most economical. In the case of the majority of gasoline cars, this critical speed is from 25 to 30 miles an hour, or even higher, while for the average electric car it is from 10 to 15 miles an hour, a speed which corresponds so nearly with the usual speed on the road that the economy of the electric is very great. Nevertheless the batteries used in the electric should be charged every night if the car has been used during the day, as it is always advisable to have the batteries fully charged. This keeps the cells in good condition.

Motor Speeds. *Types of Motor Windings.* The speed of electric vehicles is a most elusive quantity to the uninitiated, principally because the characteristics of the series-wound motor employed are not commonly understood by the layman. The series type of motor is one in which the windings of the armature and field are connected in series, i.e., so that the entire current which is fed to the motor passes through both of its elements consecutively, so to speak.

In a shunt-wound motor the field is in multiple with the armature and the entire current passes through the latter, the amount taken by the field being always proportioned to that required by the armature for the load it happens to be carrying. As this type of motor is designed for a constant speed, it is not an economical motor to use on the electric vehicle owing to the wide fluctuation of both speed and load imposed, so that its employment is comparatively rare in this field. A compound-wound motor is one having both series and shunt-coil windings on the fields. Since most commercial motors for driving machinery, elevators, and the like are of the constant-speed, compound-wound type, there is a general impression that the electric car should have a certain nearly constant speed for all road conditions.

Advantages of Series-Wound Motor. But in the series-wound motor, the speed varies inversely as the power produced. In other words, its torque, or pulling power, is highest at low speeds, which is just the requirement demanded in starting or pulling through heavy roads. This type cannot be employed for ordinary com-

mercial use, since it will instantly "run away" or race upon the load being released, but it can be employed to advantage on vehicles and in railway service because it is never disconnected from the load. "Load" in this case refers to the effort required to move the vehicles rather than the live load. Series motors are employed on the electric car because of their higher efficiency, which is of prime importance, since the object is to produce the greatest amount of useful energy from a given and limited amount of potential energy stored in the battery. Just the opposite of the gasoline engine, the chief characteristic of the series-type electric motor is the development of increased power with a decrease in the speed. Therefore, as the vehicle requires greater power for bad roads or grades, it slows down automatically and in a fixed relation to the power demanded.

High-Speed Single Motor Present Practice. Opinion and practice are divided on the subject of motor speeds. The higher-speed motors are more efficient, are better for grades and starting, but mechanical limitations frequently make them undesirable. Where formerly motor speeds ranged from 650 to 1100 r.p.m., modern practice favors higher r.p.m. rates, ranging from 1000 to 2000. Normal speeds under 1000 are not satisfactory for most conditions, the use of a low-speed type of motor being one of the causes of the low efficiency of the earlier electric cars. Another reason was the employment of two motors on comparatively light cars. This had a certain advantage in eliminating the differential, but its electrical efficiency was very low. Modern practice does not sanction the employment of more than one motor on even the heaviest of pleasure cars and on commercial vehicles up to 3- or 5-ton capacity. Beyond that point practice varies somewhat, some makers employing two driving units on the ground that no differential is needed, that starting torque is bettered by connecting the armature in series, and that damage to one motor will still permit the vehicle to travel. These advantages are more than offset by the higher efficiency possible in a single and larger electric motor, beside the benefits derived from the saving in weight of the motor and from the ability of the manufacturer to combine the two speed reductions necessary with two motors into one. This avoids some power loss in transmission from the motor to the driving wheels.

THE TRANSMISSION

Similarity to Gasoline Practice. The types of power transmission on the electric vehicle have been the same as on the gasoline car except that the order of their application has been chronologically reversed. The latter started in generally as a chain-driven machine, and quite a number of years elapsed before any other method of transmitting the power to the rear wheels was attempted. The electric, on the other hand, began as a gear-driven car, as the practice of direct-connecting electrical generators and power units, which first assumed a strong vogue shortly prior to the advent of the electric automobile, was taken as a precedent. From the point of view of operating conditions, there is considerable similarity between the gasoline and the electric machine as far as its power transmitting system is concerned.

Usual Gear Reduction. Owing to weight and space limitations, the size of the motor is correspondingly limited, and it is accordingly necessary to employ high initial rotative speeds, i. e., a very high-speed motor is essential in both cases, while the starting torque or pull must likewise be very strong in order to enable the vehicle to get under way quickly and to start readily on grades. This necessitated gearing down to a very great extent, the usual ratio on the majority of the electric vehicles being 10 to 1, i. e., for every ten revolutions of the motor, the road wheels make but one turn. In order to accomplish such a reduction without employing gear wheels of a prohibitive diameter, it was necessary to bring about this lowering of the motor speed by means of two steps, or a double train of gears. Spur, or plain straight-tooth, gears were employed at first, and proved to be not only noisy, but very wasteful of power.

They were accordingly replaced by chains in many instances, and by gears of special types, such as the *herringbone reducing gears* of the Waverley. In some instances, such as the light Baker runabout placed on the market several years ago, it was found possible to drive directly from the motor to the rear axle through the medium of a single chain, but with this exception the custom of employing two distinct reductions of speed was generally followed up to a few years ago. While there were several variations in the manner of doing this, the general principle was practically the same

in every instance, a single chain being taken from the end of the armature shaft of the motor to a countershaft extending clear across the car and having sprockets at each end. The reduction in speed from the motor to the countershaft was usually about five to one, and a similar second reduction was carried out by means of small sprockets on the ends of the countershaft, and large ones on the driving wheels. A third class of transmission consists of a combination of gearing and chain drive, such as were used on the earlier models of the Woods, and the Waverley electrics, the first reduction of which is a silent chain.

Chain Drive. During the past few years, practice in the electric field has closely followed that of gasoline car transmission design,

Fig. 20. Gear Type of Transmission

where the final drive is concerned, and in some cases anticipated it. But for the advent of several low-priced electric cars, some of which have perpetuated the single-chain drive—using a roller-type chain and sprockets as the second step in the reduction—this form would have practically disappeared. It is efficient and reliable, but not as clean and sightly as the shaft type, though this objection may be readily overcome by enclosing the chain. Economy in initial cost is one of its chief advantages and, in the case of cars which are sold at a very low figure, this is naturally of paramount importance.

Gear Drive. The self-contained unit shown in Fig. 20 is an illustration of what might be termed an instance of reducing the power plant and final drive to the last degree of compactness. Referring to the figure it will be noticed that the usual type of motor is mounted on a forward extension of the rear axle, the first step in the speed reduction being a pair of herringbone gears. Apart from this, it is practically a replica of gasoline car practice, as the axle is of the full floating type commonly employed on the latter, the second

Fig. 21. Well-Designed Unit of the Shaft-Driven Type with Bevel-Gear Rear Axle

speed consisting of the usual bevel drive, except that the propeller shaft is only a few inches long and consequently does not require any universal joints. A somewhat similar type of transmission is employed on the Broc electrics. A *full floating* type of axle with shaft drive is also a feature of the Borland, this form taking its name from the fact that the two driving shafts are not rigidly fastened at either end—either the differential or the driving-wheel end—the power being transmitted through a square-ended section of the shaft *floating* in the differential and a jaw or similar type of clutch at the wheel, the entire weight of the

car being carried by the tubes or axle housing. An example of a single reduction-shaft drive is to be found in the Century, using a Timken bevel-gear rear axle.

An equally compact form which gives a better weight distribution is the drive illustrated in Fig. 21. This bears a very strong resemblance to the driving unit of a well-known light gasoline car. It is a type which affords great rigidity with a very simple construction. The propeller shaft is practically a continuation of the armature shaft, no universal joint being necessary. At its after end this shaft meshes with a bevel gear giving a reduction of 2 to 1, while a spur-pinion reduction lowers the ratio again 4 to 1, or a total of 8 to 1 between the high-speed motor and the driving wheels.

Fig. 22. Combined Bevel and Spur Gear. Double Speed Reduction of the Axle Shown in Fig. 28.

The arrangement of the two speed reductions in the axle is shown by Fig. 22. These bevels have an adjustment by means of a collar which can be loosened or tightened until a perfect adjustment is obtained. The larger bevel is mounted on a short jackshaft carried on ball bearings on both ends, and upon this shaft is mounted the small spur pinion. On each side of the jackshaft is a threaded collar which allows for the movement of this shaft either in or out, which, in conjunction with the adjustment of the bevel gears, permits of a perfect setting of both sets of gears. The housings consist of tapering swaged steel tubes which extend from each side of the differential housing through the brake housings and the wheels, while the driving effort is taken on the combined torsion and radius rods pivoted on saddles on the axle just inside the brake drums and on the rear end of the motor housing.

In this, as in all representative types of final drive on electric pleasure cars, annular ball bearings are used throughout. One of these bearings is shown just forward of the small bevel pinion in the two-speed reduction axle. This is an advanced type of bearing which the automobile has been largely responsible for developing. It is far more costly than even the very best of plain bearings, but it cuts friction down to a practically negligible factor, while it will also run with a very small supply of lubricant and requires a minimum of attention. Such bearings are now universally employed, not alone in the electric motors of these vehicles, but also for the countershafts and wheels, and in similar locations. If the ball bearing is not employed, the taper roller type is substituted, the latter being very much favored for wheel bearings on both gasoline and electric cars, owing to their ability to withstand heavy thrust as well as radial loads.

Worm Drive. *Development.* What would appear to be the ultimate development in electric car transmission, however, has been the adoption of the worm drive; and, in taking it up so generally, the electric vehicle manufacturers have anticipated what is bound to come on the gasoline pleasure car in the near future, as it already has in England to a great extent. In this adoption, the history of the electric self-starter on the gasoline car has been repeated, in that experiments were carried on for a number of years with little progress apparent to the world at large, and then, within a comparatively short time, the worm drive came into more or less general use. In this case, however, most of the research work was carried out in England, and a considerable proportion of the worm drives used on American electric cars are imported from that country. In itself, this form of drive is not a novelty, the Hindley worm drive, made in Philadelphia, having been employed on electric elevators for quite a number of years. Its successful application to the automobile represented far more of a problem than the bevel-gear type as, unless correctly designed and machined to the highest degree of accuracy, the friction and thrust are excessive and the resulting efficiency is low.

Advantages of Worm-Gear Transmission. Consideration of the fundamentals of electric vehicle design, i.e., a light high-speed motor and a comparatively slow axle speed, will make apparent the

great desirability of the worm drive in this connection. It represents the most practical means of power transmission from a high-speed motor direct to the rear axle by means of a *single reduction.* This means saving in weight and the avoidance of the power loss entailed through the use of the second reduction in the gear ratio otherwise necessary. A further advantage is its silence in operation, the worm and worm wheel representing the closest approach to this much-to-be-desired feature that is attainable in the transmission of power by direct metal contact. While its initial cost is as high, if not higher, than even the best forms of double reduction, it eliminates several parts, and accordingly affords a simpler form of construction with a more direct transmission of the power.

Fig. 23. Rauch and Lang Worm and Gear

Details of Worm Drive, Rear Axle, and Brake. The worm is of alloy steel while the worm wheel is bronze, a multiple thread of long pitch being cut on the former while the latter is made with a special form of tooth, as will be noted by the Rauch and Lang worm shown in Fig. 23. This is an American type developed by the makers of the Rauch and Lang electrics especially for this purpose. In both this make and the Woods electric the worm meshes with the worm wheel on its upper side, the relation being shown by Fig. 24, which illustrates the Rauch and Lang motor and propeller shaft in addition. Two universal joints, one of them of the slip type to allow for relative longitudinal movement between the motor and rear axle, are employed. A brake is placed on the forward end of the armature shaft, this showing in the same illustration. Fig. 25 shows the complete Rauch and Lang motor and driving unit. A torsion

rod, parallel with and below the propeller shaft, also serves as a distance rod between the motor and rear axle and takes all torsional or twisting stresses to which the axle is subjected when under power. The forward end of this torsion rod is connected by means of a

Fig. 24. Rauch and Lang Motor, Shaft, Universal Joints, and Worm and Gear

flexible joint of the ball-and-socket type, with the top of the torsion rod link, which in turn swivels on the rear motor yoke. The rear end of the torsion rod is taper fitted into a nickel-steel forging, which

Fig. 25. Rauch and Lang Motor and Rear Axle Unit

sets into a vertical taper bearing in the front end of the axle housing. The method of hanging the torsion rod leaves the rear axle housing perfectly free to adjust itself to the relative movement of the axle and frame due to the compression of the springs. The latter are of the seven-eighths elliptic type, the upper and lower members of

Fig. 26. Rear View of Rauch and Lang Worm Drive Chassis

which are shackled at the rear ends so that they are flatter than usual, thus giving better riding qualities. They are held at three points, which decreases the tendency toward lateral movement or side sway, the driving strains being taken on the front ends of the lower leaves. The worm and worm wheels are adjusted in perfect alignment in assembling the unit, and the latter is housed in, so that no adjustments can be made from the outside. Contrary to the bevel-gear drive, which in course of time wears out of alignment, a worm gear continues in alignment regardless of wear, within prac-

Fig. 27. Forward End Torsion Rod, Spring Suspension and Brake Details on Rauch and Lang Car

tical limits, and once properly adjusted can only be deranged by subsequent adjustments. A better idea of the various essentials of the drive will be obtained by reference to the rear view of the Rauch and Lang worm-driven chassis, Fig. 26. As mentioned previously, a brake is carried on the armature shaft on this car, the second set being of the internal expanding type operating against the drums shown attached to the driving wheels, Fig. 27. On the Argo and several other cars both sets of brakes are of the internal expanding type, the details of this type of brake construction being shown in Fig. 28.

The Rauch and Lang worm drive consists of a combination radial and thrust annular ball bearing at each end of the worm and on each side of the worm wheel. Upon the correct alignment of mounting and proper provision for taking thrust, depends the success or failure of any worm drive.

THE CONTROL

Unlike the gasoline car, in which the control of its speed and climbing abilities is divided between a provision for changing the gear ratio existing between the motor and the driving wheels, and a means of increasing the speed and power output of the motor itself through the admission of more fuel and advancing the point of ignition, that of the electric vehicle is entirely electric. This is largely responsible for its great simplicity, all changes in either direction being effected through a single small lever, the manipulation of which calls for no more skill than the shifting of a trolley-car controller. But there is quite as much latitude of design to be found in the methods of control of electrical vehicles as there is in the method of transmitting the power to the rear wheels, though, as in the case of the power transmission, there is more or less similarity in the principles involved.

Counter-E.M.F. Neither a steam engine nor a gasoline motor can be given "full throttle" to start it without danger of damaging it. This is due to the inertia of the moving parts, which must be set in motion gradually and allowed to attain a certain speed before full power is developed. As the electric motor has no reciprocating parts, and its revolving armature is carried on the finest type of anti-friction bearings, the factor of inertia is prac-

tically negligible in so far as it affects starting. It has already been mentioned that the passage of too great an amount of current through a wire, i.e., too great for its carrying capacity, has a heating effect. The heating increases in proportion to the excess of current flow over the safe capacity of the wire until it is sufficient not only to burn off the insulation on the wire, but even to fuse the wire itself.

Now the resistance of the motor armature windings is very low, but when the armature is revolving, the electrical resistance is increased by two factors—first, a counter-e.m.f., which is developed by virtue of the rotation of the armature, and second, the fact that the wire in the windings becomes warmer, it being a peculiar and inexplicable phenomenon that the resistance of a wire increases in proportion to its temperature.

Controller. The inability of the motor to carry more than a fraction of its normal operating current when starting makes necessary the use of something equivalent to the throttle of the steam engine for accomplishing this necessary control. As not alone the character of the external source of power—in this case the battery—is capable of manipulation, but also the internal relations of the power-producing elements of the motor itself—the armature and the field—are susceptible of various changes, it will be evident that the speed range possible under the circumstances may be made as wide as the designer desires. Ordinarily, most electric vehicles are provided with a controller giving five speeds forward and two or three reverse.

Drum Type. In the majority of cases, the controller employed on the electric automobile is of the drum type, and is practically a duplicate on a reduced scale of that employed on street railways, except that the automobile controller is what is known as a *continuous torque* type. That is, there are no dead spots or idle gaps between different speeds, the current always being on except when the controller handle is at the neutral position. This insures a continuous and gradual increase in the speeds without any jerking between the various steps, and prevents a sudden heavy load being placed on the motor, as would be the case where a pause was made in shifting the handle of the controller over a dead gap. The motor continues to run at the lower current value until the next set of contacts on the

controller is actually delivering a greater voltage or more current. The drum, or cylinder, is of insulating material and has mounted on it a number of copper segments of substantial thickness. These are so spaced that they make contact with corresponding fingers, also of heavy spring copper, that are held stationary alongside the drum. The copper bars on the drum are "grounded" to provide the continuous torgue, that is, they have a common return permitting the current to reach the motor constantly.

The drum in this instance is seen to be but a section of a cylinder, on the curved surface of which the spacing of the bars will be apparent. It will also be seen that there is a corresponding finger making contact with each bar, or in a position to do so when the drum is turned to bring it around to that particular point. These fingers are held against the drum very firmly by springs. The open socket visible at the lower end of each finger is intended to receive the bared copper wire of which it represents the terminal connection and it will at once be evident that it is provided with a greater number of contacts than is the first controller shown. It should be mentioned here that the drum is spring controlled as well as the contact fingers, and is also provided with notched stops in order to hold the contacts on it directly under the ends of the fingers. In the present instance, which represents the type of controller employed on the Detroit car, the contact fingers themselves are directly attached to leaf springs, which are plainly in evidence. The terminals mentioned are also to be seen along the bottom, while at the left there is an extension of the shaft on which the drum is mounted. This carries a lever by means of which the drum may be revolved in order to give the different speeds, forward and reverse. The latter is generally accomplished by means of a pole reversing switch, most frequently incorporated directly in the controller itself, and which always remains locked under normal running conditions. In order to bring the reverse into play, it is usually necessary to depress a small pedal or similar release, in order that the driver may not inadvertently start the car backward.

Flat Radial Types. A good illustration of a totally different form of controller is found in the Rauch and Lang cars, and is known as the *flat radial* type. In the construction of the earlier models of the Rauch and Lang car, it was combined with the motor

and countershaft unit, but is now mounted independently and in the accompanying illustration, Fig. 34, it is shown separately. Instead of being mounted on a drum, the contacts are placed on a stationary segment representing about one-fourth of the arc of a circle. A pivoted arm, held at what would be the center of the circle, is so mounted that it may be turned in order to make contact with the different blocks, these in turn being electrically connected to the terminals shown attached to the upright piece at the left of the controller. As a matter of fact, there are two separate series of contacts around the arc, and two movable levers arranged to be moved over them. In this case, the moving contacts are made of thin copper leaves assembled together and are held against the contacts by a spring.

Fig. 34. Flat Radial Controller

Fig. 35. Flush Type of Controller

Flush Types. Fig. 35 illustrates a type of controller which is designed to be countersunk in the seat of its surface so as to be flush with the latter. This is a plan view, showing the controller as seen from above, the pattern being one in which the drum is a complete cylinder. The left-hand panel of the controller holds the fingers and contacts for the forward speeds, while those at the right are the reverse speeds, there being four in each direction in this case. Further to the right is to be seen the operating lever, the pinion visible on the end of the drum shaft constituting part of the mechanism for advancing or returning the drum. This consists of a rack in the shape of a quadrant which meshes with the pinion in question. At the extreme left is shown the spring-controlled stop which prevents the drum from being rotated more than one space at a time in either direction, and holds it with the fingers pressing directly on the contacts at each point of its revolution. The type of controller employed on the Baker cars is shown in Fig. 36.

Fig. 36. Baker Controller and Operating Lever

Magnetic Type. To facilitate the handling of the comparatively heavy current that is necessary in starting, changing speed in going up hill, and the like, without having to employ wiring of large size to a point near the hand-control lever, a modification of the multiple-unit system of control as used in electric railway service, and particularly on elevated trains, has been applied to the electric automobile. In this system only a current of small value is actually passed through the hand-controlling mechanism, which takes the form of a small "controller box", as shown in Fig. 37, which represents part of the control of the Ohio. The controller of the Century is shown in Fig. 38. By setting this to the speed desired, current is passed through a magnet in the controller proper. The armature of the magnet is attracted, and in so doing it closes a switch or contact for the corresponding speed. There is a magnet or solenoid for each speed ahead and reverse, which are so connected that, in

changing to a higher speed, the contact of the speed below is not broken until either the switch giving the higher current value is closed, or the current is shut off, thus releasing all the magnets and

Fig. 37. Control Disk of the Ohio Magnetic Controller
Courtesy of Ohio Electric Car Company, Toledo, Ohio

obtaining the advantages of the continuous-torque type of hand controller. The arrangement effected by the opened and closed positions of the various magnets determines the direction and

Fig. 38. Magnetic Controller of the Century Electric Car

magnitude of the current in the motor circuit in a similar manner to that provided by the segments and fingers of the drum controller. The essential difference between the magnetic controller and the

ordinary type is that the former is electrically operated, while the latter is mechanically operated. Hence its location is not governed by the necessity of mechanically connecting it with the hand lever through rods, gears, or chains, and it may be placed in any convenient location. In the Ohio it is placed under the seat. The various speeds are obtained by turning the disk on the end of the contactor box near the driver's hand. Turning to the right gives

Fig. 39. Wiring Diagram for Primary Circuit of the Ohio Magnetic Controller

the various forward speeds in consecutive order. The neutral position is as far to the left as the disk will go; by pushing the button on top the controller may be turned still further to the left to give the reverse speeds. When in the neutral position it may be locked there by pushing in the button at the back, and the controller cannot then be operated until unlocked with a key. Buttons are also provided for ringing the bell and operating the magnetic brake. The contacts are made by spring-held carbon brushes pressing against the inner face of the disk. In this system of control there are two independent circuits—the primary circuit passing through the mag-

netically-operated switches of the controller from the battery to the motor, and the secondary circuit, which handles the current of lesser value employed to operate the magnets, and which is controlled by the movement of the disk mentioned. The primary wiring diagram of the Ohio is shown in Fig. 39, and the secondary wiring diagram in Fig. 40.

Duplex Control. To facilitate the handling of closed cars of the brougham and other large types of enclosed cars seating five or more passengers, duplicate-control wiring and duplicate-brake pedals

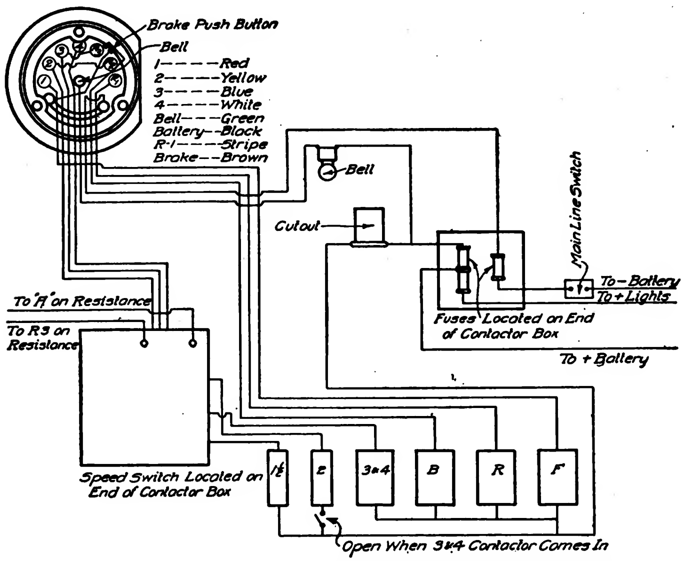


Fig. 40. Wiring Diagram for Secondary Circuit of the Ohio Magnetic Controller

are provided at two positions; one forward, designed to be operated from a front seat, and the other similarly located with relation to the rear seat on the same side. Brake pedals and steering connections are also duplicated, so that to shift the control of the car from one location to the other, it is only necessary to release the steering column at one place and insert and lock it in the socket provided for this purpose at the other. This enables the driver to keep the way clear ahead no matter how many passengers are carried and also drive from the rear seat when the load is light.

Care of Controller. The contacts of the hand-operated type of controller should be inspected at intervals to note whether they are

making proper contact or not. In case the spring of one of the fingers loses its tension, an arc is apt to form between it and the segment on the drum and burn the metal. The presence of such an arc will be noted by a peculiar hissing sound which will be plainly audible if the cover of the controller box is removed and the car run in a comparatively quiet place. This action will also take place to a certain extent if the controller is held between the notches in changing speed. The blistered surface of the metal thus resulting will make poor contact, and will continue to burn more and more unless this condition is remedied by sandpapering the finger and correcting the tension of the spring so that contact is made all over the surfaces that touch. If a finger has become badly burned, it should be replaced and the new one adjusted to an even, moderate tension. When necessary to face the fingers to the drum, the sandpapering should be done on the fingers themselves rather than on the segments of the drum, as the latter are not so easy to replace. The drum segments should be kept bright and clean, and should be lubricated occasionally by wiping with a linen rag and some vaseline.

Methods of Control. As it is equally important for the owner of an electric vehicle to familiarize himself with the manner in which the amount of current sent through the motor is controlled, quite as much as with the apparatus for effecting this, it has been thought advisable to devote a short section to this subject. Before taking up this matter, it will be well to return momentarily to a previously discussed subject of series and parallel connections.

Series and Multiple Connections. Each cell of a storage battery is a complete self-contained unit capable of delivering current of a certain amount according to its size and capacity, at an electrical pressure of slightly more than two volts when fully charged. For purposes of illustration, each individual cell may be likened to a pump, capable of exerting a pressure of two pounds. It will be quite apparent that if 24 such pumps, corresponding to the 24 cells of a 48-volt storage battery, were connected together—the outlet of the first to the inlet of the second and so on throughout the entire 24—the series of units would be capable of producing a pressure of 48 pounds. The water delivered could accordingly be forced 24 times as far, or as high, as one pump could send it, but the quantity raised would only be that of which one unit was capable. This analogue

affords a very clear idea of what is meant by a series connection, as the statement just made regarding the ability of pumps so connected applies literally to the storage cells under the same conditions. Again taking the 24-cell battery as an illustration, this being the former standard for light pleasure vehicle use, it will be seen that the output of the battery connected in series, i. e., the positive of one to the negative of the next and so on throughout the set, would be the ampere-hour capacity of one cell at 48 volts. The voltage is seldom constant, but ranges from 2.2 to 1.7 volts per cell, according to the state of charge that the cell is in at the time; but when a number of cells are connected in series, the voltage of the battery thus formed will always be that of the voltage of one cell multiplied by the number in the battery. For purposes of reference, it is customary to consider the potential of the storage cell as 2 volts.

To return to the analogue of the pumps, where the conditions are such that a greater quantity of water is required, but it is not necessary to raise it to more than half the height to which the 24 pumps in series are capable of sending it, they may be arranged in two series of 12 each. Double the volume of liquid may then be raised to a height represented by the ability of the 24-pound pressure developed. The two groups of pumps are still in series, so far as they alone are concerned, and each group would have but the capacity of a single pump at twelve times its pressure. But when the inlets and the outlets of the two groups are brought together in the case of either pumps or storage cells, the volumetric capacity is increased to two units at a pressure of 24 pounds or volts. If, on the other hand, all the inlets were brought together into one connection and all the outlets into another, there would result a capacity of 12 pumps, at the pressure of but one. This last-named arrangement is termed a *multiple* connection, while that described above is a combination of the series and multiple connections, and is accordingly designated by the term *series-multiple.*

Given 24 cells or more, the number of series-multiple combinations possible is quite extended, but it will be evident that those at either extreme of the range would be useless for all practical purposes in the running of an electrical vehicle. It is accordingly customary to assemble the cells in sets of six or eight connected in series, which cells are securely packed in oak cases, the number of the units

employed depending upon the voltage of the motor of the vehicle.

Resistance in Circuit. Another source of control is to be found in the motor itself. It will be recalled that the latter generates power by means of the alternating magnetic attraction and repulsion of the sections of the armature by the field magnets. The strength of the latter, as well as that of the electromagnets composing the armature, is naturally dependent upon both the amount of current sent through them and its voltage. One of the simplest forms of control is naturally that in which the entire battery is in series with the motor, and in which the relation of the two undergoes no change. In such a case, resistances of the type shown in Fig. 41 are employed

Fig. 41. Controlling Rheostat

to cut down the current sufficiently to give what are usually termed the *starting speeds*. In every case, the full energy of the battery is being drawn upon, but only a part is being utilized on these first speeds, the remainder being dissipated by the resistance in the form of heat. In view of the very short period during which they are employed, the use of resistances in these starting speeds is not a detriment. This system of control is to be found on the Rauch and Lang cars, among others, and has the great advantage of discharging all the cells of the battery uniformly. All the speeds are obtained at the same voltage and the motor is working at every position of the controller handle, so that there are accordingly no dead spots and the circuit is never open, even momentarily. A similar system of

control is employed on the Baker vehicles. This will be evident upon a little study of the accompanying diagram, Fig. 42, illustrating the wiring and all the connections. The large squares, marked plus and minus, represent the groups of cells into which the battery is divided. The individual cells in each group are connected in series and it will be seen by tracing the connections that the groups are likewise in series, a positive being connected to a negative and so on throughout.

Wiring Diagram. Wiring diagrams appear extremely intricate to the uninitiated at first sight, but in each instance the course taken by the current may easily be followed after a little study, and as familiarizing himself with all the wiring and connections of his car is a

Fig. 42. Control Wiring Diagram

part of the education that no electric vehicle owner should overlook, it should not be slighted. The diagram received from the manufacturer of his car will be a blue print similar to the one from which the accompanying illustration was taken, so that it may be studied here as well as at first hand. Familiarity with one of these diagrams will prove an "open sesame" to all others, for, while they all differ to a greater or less extent, it will be easy to trace the different circuits, once the rudiments are known.

The fact that all of the cells in the battery are in series has already been mentioned. It will be seen that there are 24 cells in the battery, giving a working potential of 42 to 60 volts according to the state of charge. The different points of the controller are represented by the group of parallel bars in the lower center of the

drawing, marked R-4, R-2, etc. In this case it will be noted that there are four connections of this nature, R-1 to R-4, these representing resistances to cut down the current for starting. They are accordingly known as *starting speeds*, and are only designed for getting the vehicle under way, an operation that calls for a heavy torque or pull on the part of the motor. This requires a large amount of current and, as already mentioned, it would be apt to burn out the motor windings if sent through the latter before it had attained sufficient speed to build up its counter-e.m.f. to a point where the full current may be safely handled. The external resistances themselves are represented by the bars marked in the same manner, seen diagonally to the left and above the controller on the diagram, the connections between the two being easily traceable.

Further points on the controller are designated as F-1 and F-2, and FF-1 and FF-2, and refer to the connections for altering the relation of the field and armature. Electric motors employed on automobiles are generally of what is known as the *series type* in which the armature and fields are normally in series with one another. In other words, the entire current passes through the complete winding of the motor. By varying this relation in several ways, several steps in the speed control are possible without the intervention of any resistance. For instance, in the control, as illustrated, the first speed is obtained by placing the field in series with a resistance, giving a car speed of 8 miles an hour. By cutting out part of the resistance and still maintaining the same relation, the car speed is increased to 10 miles an hour, corresponding to the second point on the controller. At the third point, the resistance is eliminated altogether, resulting in an increase to 12 miles an hour. A further increase to 14 miles an hour is obtained by shunting the fields, while the fifth speed of 16 miles an hour results from placing the field in series-multiple. The last point on the controller shunts the series-multiple field and gives 19 miles an hour.

Office of the Shunt. The term *shunt* may be explained by turning again to the water analogy. Electricity, water, or anything else under pressure will naturally follow the path of least resistance. Take, for instance, a two-foot water main, with a one-inch outlet tapped into it. The amount of water that will flow through the one-inch pipe is not alone dependent upon the pressure

in the main, but likewise upon the resistance offered by the one-inch pipe. This, by analogy, is practically an application of Ohm's law. Substitute for the water main an electric circuit. At a certain point, connect to it a by-path in the shape of another circuit of smaller wire, and in consequence, representing a greater resistance. The current can pass through these two circuits simultaneously and the amount of current in the second, or shunt circuit, will be smaller than that flowing in the main circuit. In fact, the current will divide itself inversely as the resistance; that is, if a shunt has ten times the resistance of the wire in the main circuit between the terminals of the shunt, this shunt circuit will carry only one-tenth of the total current.

The best example of a shunt connection is to be found in the case of the volt-ammeter, as shown in Fig. 42. For convenience, the voltmeter and ammeter (ampere-meter) are combined in a single case as if they were one instrument, but it will be noted that the connections are the same as if both were independent. As the voltmeter is always in circuit, whether the car is running or not, it is wound to a very high resistance so as to consume the minimum amount of current for its operation. The shunt marked on the lower part of the diagram, just under the position of the instrument, is really a part of the ammeter itself. Where only small quantities of current are to be measured, the full strength is usually passed directly through the ammeter, but on an electric automobile, this would not be practicable in view of the wide range and the sudden variation of the storage-battery current, which in starting frequently takes the form of a heavy surge. The instrument is accordingly designed to employ but a fraction of the total current, this fraction bearing a direct relation to the total current passing, the scale reading of the ammeter being the same as if the full strength of the current passed through it.

It will be evident that any circuit, such as the field winding of the motor, when placed in shunt with its supply circuit, will only take an amount of current depending upon the ratio between its resistance and that of the main circuit, and that economy in current consumption results. This explains its employment for two of the higher speeds of the car, the wiring diagram of which is illustrated in Fig. 42. It will be noted that this connection is only employed for the higher speeds; in one case, the field windings being in series them-

selves, and the whole in shunt with the main circuit, to give 14 miles an hour; and in the second, the field windings themselves being in series-multiple and in shunt with the main circuit to give a speed of 19 miles an hour. This is due to the fact that at the higher speeds, only a relatively small amount of power is required to keep the machine moving. Electric vehicles as a rule do not run at speeds high enough to make wind resistance a factor of great importance, and as a result operate under ideal power conditions when once under way. In other words, the *draw-bar pull,* by which is meant the effort necessary to keep the vehicle moving, is very light. At starting, however, in common with other cars, it is heavy, so that it will be evident that the shunt connection is not applicable to the starting speeds. Its rôle is that of economy, rather than power, and to obtain the latter the series connection is necessary.

Fuses. The fuses are a part of the electrical equipment of the car, mention of which may be appropriately made in this connection, as their function is that of acting as a safety valve in the control. The varying resistances of different kinds of metals have been explained, as well as the heating effect incident to sending a current through a wire, particularly where the latter is of a size too small to carry the current. It is well known that lead and similar materials have a very low melting point, and advantage has been taken of this in connection with the phenomenon just referred to, to make what are known as *electric fuses.* These are strips of lead alloy of accurately determined sizes, each size being designed to carry a certain amount of current at a certain voltage. This is known as the *capacity* of the fuse, and between it and the amount of current that the motor or other apparatus which the fuse is designed to protect can safely stand there is an ample margin of safety. In consequence, whenever there is a rush of current through the circuit, as when the controller lever is pushed sharply forward toward the *full on* point, and the brakes happen to be holding the car, the fuses will "blow out" or melt, and save the motor from destruction.

CARE AND OPERATION OF THE ELECTRIC

CHARGING THE BATTERY

SOURCES OF CHARGING CURRENT

Sources of Direct Current. *Small Generators.* There are few towns, or even villages, in this country at the present day that cannot boast of electric-lighting facilities, so that the owner of an electric vehicle will find it possible to obtain charging current for the maintenance of this type of automobile regardless of where he lives. In case he should reside too far outside the corporate limits of a village to find such service at his command, or in case he is of a sufficiently mechanical turn of mind to undertake it, he will find apparatus for generating the current on his own premises available for a comparatively moderate outlay. Though not the simplest, a small direct-current dynamo driven by a gasoline engine requires but little attendance, and will prove by far the most economical method of charging. This is particularly the case where the generating set's chief employment is that of lighting the house, although where an isolated plant may be installed, the owner of an electric vehicle will find it a great advantage for charging purposes alone.

The coming of the small gas-electric farm lighting plants has brought into the industry a form of battery charging apparatus that is very compact, reliable and one that is inexpensive to operate. Most of these plants, however, operate on 32 volts and it is then necessary to charge the batteries of the electric vehicle in parallel. When 110 volts are available from a small gas-electric plant, charging may be accomplished in the ordinary method, using a bank of lights or a rheostat as a resistance to regulate the charging rate.

This may be seen from the fact that in small towns and villages rates for electric current are usually high. The power unit, the *watt*, has already been explained. A kilowatt is 1000 watts, and electric current is sold by the kilowatt hour, which means the employment of one kilowatt of current for one hour. Where current is purchased in comparatively small quantities, the rate is seldom less than 10 cents per kilowatt hour, and sometimes 15 cents, or more. With an ordinarily efficient generator and gasoline engine, current may be produced in a small isolated plant for less than 5 cents per kilowatt hour.

The average runabout battery requires 75 to 80 ampere hours

for a charge, while a surrey, phaeton, victoria, brougham, or similar type will need 100 ampere hours.

Service Mains. If the current be taken from the service mains at 115 volts, the charge for the runabout battery would be $75\times115=8625$ watt hours, or more than $8\frac{1}{2}$ kilowatt hours. The cost of this would be 86 cents at a 10-cent rate. Even where current is to be had at more favorable rates, such as 7 or 8 cents a kilowatt hour, a small engine and dynamo are very much more economical where no extra attendance has to be figured on.

Sources of Alternating Current. Turning now to the usual source of electricity, the *alternating current,* one is confronted with

Fig. 43. Motor-Generator Set, 115 A. C. to 125 D.C.

the fact that the *charging current must in all cases be "direct," never "alternating."*

Alternating current has been found much more practical for long-distance transmission and distribution, and its use is now very general throughout the country, so that where the owner of an electric vehicle decides to fit up his own garage for storing and charging the car, the first thing to be considered will usually be some means of rectifying the alternating current, that is, making it direct. This may take several different forms, such as the motor-generator set and the mercury arc rectifier, but for reasons which will be made plain the mercury arc rectifier will be found the most practical and economical apparatus for the purpose.

Motor Generator. Where there is a considerable amount of charging to be done, the motor-generator set is frequently employed.

Fig. 44. Motor-Generator and Charging Panel for Charging Twelve Electric Trucks
Courtesy of Curtis Publishing Company, Philadelphia

This consists of an alternating-current motor and a direct-current generator combined in a single unit, both armatures being on the same shaft, the supply current simply being utilized to run the motor. A set of this kind is shown in the accompanying illustration, Fig. 43. The apparatus is designed to take alternating current at 115 volts and generate a direct current at 125 volts. In Fig. 44 is shown a very well-arranged and complete motor-generator charging plant.

Mercury Arc Rectifier. Owing to its simplicity, as well as to the fact that it is entirely automatic in action, the mercury arc rectifier has come into very general favor for storage-battery charging on a small scale. The apparatus itself is shown in Figs. 45 and 46, giving, respectively, a front and rear view; the connections are shown diagrammatically in Fig. 47. It will be seen that the panel board of the instrument incorporates everything necessary for regulating the charge, including a voltmeter, an ammeter, resistance, main switch, starting switch, circuit breaker,

and fuses. The *circuit breaker* is a device designed to protect the apparatus with which it is connected by opening the circuit when there is an excess of current, or when the current supply is accidentally cut off. By opening the circuit as soon as this occurs a rush of current through the apparatus is prevented when the service is resumed. Should it fail to act, the fuses represent the second step in the protective link, but naturally their only func-

Fig. 45. Switchboard, Front View

Fig. 46. Switchboard, Rear View

tion is to rupture the circuit by melting under the heating effect of an excessive flow of current.

The mercury arc rectifier consists of a glass vessel, Fig. 48, from which the air has been exhausted and a certain quantity of metallic mercury inserted. The tube also has fused into the glass the several connections necessary. The one negative terminal, called the *cathode,* is sealed into the bottom of the tube while two positive terminals, called *anodes,* are on opposite sides and a short distance above the cathode. The anodes are graphite and the cathode mercury. When

at rest, there is no electrical connection between them. A starting anodes is accordingly provided. If the tube be rocked gently after the switch has been closed, an arc is established between these two points. This liberates sufficient mecury vapor to start the main arc; the starting switch is then opened. An automatic starting device for use when charging at night, takes the form of a shunt coil and a solenoid, in which a plunger operates. When the arc is broken, the current is shunted through this solenoid and the plunger shakes the tube gently, thus re-establishing the arc and continuing the charge.

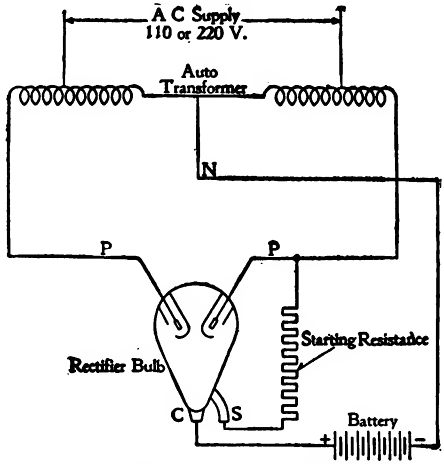


Fig. 47. Wiring Diagram for Mercury Arc Rectifier Circuit

METHOD OF CHARGING

Making Proper Connections. Batteries are not usually shipped with the vehicle itself, but are packed separately in a charged condition; as a freshening charge is required before the battery is used, it will prove an advantage to carry this out before placing the battery in the car. The groups of cells must be connected in series—the plus terminal of one group to the minus terminal of the next, and so on, *the final positive and negative terminals of the entire set being connected respectively to the positive and negative terminals of the source of the charging current.* The charging current must flow into the battery at the positive pole; a wrong connection will not

Fig. 48. Mercury Arc Rectifier Tube

only fail to charge it, but will do a great deal of damage and seriously impair the life of the battery.

Determining Polarity. Where the polarity of the charging terminals is unknown, the simplest method of determining it is to take a glass of water into which a few drops of acid or a little salt has been put. Place the wires in it, *taking care to keep them well separated.* Bubbles of gas will form on both of the wires, but one will give off gas much more freely than the other. This is the negative pole and should be attached to the negative charging terminal of the battery. The other wire will give off comparatively little gas and will rapidly blacken. This is the positive pole. There are numerous other tests equally simple, but as this calls for apparatus easily obtained anywhere, it will be an advantage to memorize it, particularly as occasions will arise when the vehicle will have to be charged away from home in the absence of the usual facilities. The wire or connections to the battery from the charging side must be of ample size to carry the heaviest current used in charging without undue heating. The sizes used in the car itself form the best guide for this.

Voltage After Charging. The operation of charging will be the same whether the battery is in or out of the vehicle, but as the battery was fully charged when shipped, this initial charge will be a short one. But the greatest care must be taken to charge the battery fully. The voltage per cell should reach 2.55 volts, with the current still on, when the cell is fully charged. This would mean 60 to 62 volts for a 24-cell battery.

These voltages, Table II, are approximate and are intended for guidance only. A battery when cold will show a higher voltage than one at a higher temperature, and the same thing is true of a new battery as compared with an old one. It is not safe to regard a fixed voltage as the end of the charge, but a maximum voltage for the battery in question.

The rubber plugs should be removed from the cells during the operation, as the cells will be gassing very freely toward the end of the charge. This gas is hydrogen and, as it is not only highly inflammable, but likewise very explosive when mixed in certain proportions with oxygen, care must be taken not to bring a naked flame anywhere near the battery while in this condition. The plugs may be left out for a short time after the charge is finished to permit the

TABLE II

Charging Voltage for Lead Batteries*

Number of Cells	Volts At	
	Start	Finish
12	26	31
14	30	36
16	34	41
18	39	46
20	43	51
22	47	56
24	52	61
26	56	66
28	60	71
30	64	76
32	69	81
34	73	87
36	77	92
38	82	97
40	86	102
42	90	107
44	95	112
46	100	117
48	105	123
50	110	128

*Cushing and Smith, *Electrical Vehicle Handbook.*

escape of the gas. The latter carries more or less of the acid electrolyte with it in the shape of a fine spray, and care should be taken to keep this spray from falling on the clothes or similar objects, as it causes ruinous stains, and only a comparatively small quantity is required to burn holes in cloth.

Temperature of Battery. When the battery is out of the vehicle, as in the case under consideration, the matter of temperature is not so important, but when it is in the vehicle, precautions must be taken to provide all possible ventilation. The charging causes a rise in the temperature of the cells and this should never be allowed to exceed 110° F. under any circumstances. The lower it can be kept the better, and a battery which is never allowed to exceed 90° F. while under charge will last much longer and give better service. The reason for this is to be found in the fact that the heating causes the active material in the grids to expand. If this expansion be excessive, as where the temperature is allowed to get too high, the material is apt to bulge completely out of the retaining pockets, so that it does not return when cooled off again. This destroys its

connection with the lead grid, cutting down its conductivity and greatly lowering the efficiency of the cell. Furthermore, after this bulging of the paste has occurred, there is the possibility at any time that flakes of active material will drop down below the plates and cause a short-circuit. Even if it does not cause this trouble, the accumulation of the material in the bottom may soon be enough to short-circuit the whole cell unless it is of the type provided with an especially deep space below the plates. The temperature should accordingly be noted from time to time during the charge and, if it passes safe limits, the charging rate must either be reduced or discontinued altogether in order to give the cells an opportunity to cool off.

Experience has shown that the best results are obtainable from a storage battery when its temperature is maintained between 70° and 90° F. during both the charge and discharge. A considerably lower temperature will materially reduce the available charge of the battery, but this does not tend to injure it in any way, as a return to normal temperature restores its capacity. This is not true of a higher temperature, however, for if it is kept above normal for any length of time the wear on the plates is excessive.

Charging Rate. Every battery has a certain charging rate, and this should be taken from the chart sent with it by the manufacturer. It will be found that there are two rates—a starting rate and a finishing rate—and, as it is during the final part of a charge that the greatest wear falls on the battery plates, instructions regarding the strength of the current to be employed for starting and finishing the charge should be closely followed. The more slowly a battery can be charged within reasonable limits, the better will be its condition at all times, and the longer its life. It is not always convenient, however, to give a battery as slow a charge as desirable in electric vehicle work. On the contrary, the car is often wanted at short notice not long after the battery has been discharged, and consequently it is abused by being charged at an injurious rate for a short period. Theoretically, 10 amperes for ten hours and 50 amperes for two hours are the same and should give a battery capacity of 100 ampere hours. Instructions furnished by the manufacturer as to rates of charge should be noted and carefully complied with by the owner.

The manufacturer specifies that each type of cell shall be started at a certain charging rate, say, 10 amperes. The charging

rheostat is manipulated until the ammeter shows that the amount of current in question is going into the batteries. Fig. 50 shows a typical form of a charging rheostat. This rate is maintained until the voltmeter indicates that a certain potential has been reached, which is usually a voltage of about 2.55 volts per cell, measured with current flowing. The charging rate should then be reduced to 4 amperes, which causes a considerable drop in the battery voltage. This reduced charging rate is then maintained until the voltage again rises to the point at which the voltmeter stood when the current was reduced, i.e., until the voltage ceases to rise, which will generally be the same as the voltage at which the high rate of charge must be reduced. The total voltage of the battery is usually taken as an indication, and when this fails to reach the desired figure, it is usually a symptom that some of the individual cells have defaulted. The remedy for this is given later.

Fig. 50. Typical Charging Rheostat

Precautions. At the end of both the *starting* and *finishing* periods, the cells will be gassing freely, i.e., giving off large quantities of hydrogen, and for this reason the battery space of the vehicle should be open and the room in which the charging is done should be well ventilated. In addition to being highly inflammable and explosive, this gas is also very irritant to the throat and lungs and when present in any quantity causes constant coughing. Nothing but electric light should ever be employed in a private garage used for the charging of an electric car.

There are a number of other precautions to be observed when

placing the battery on charge in the vehicle besides that of providing ample ventilation, as already mentioned. The controller handle should be locked in the off position, the lamps switched off, and the bell should not be rung during the progress of the charge. The reason for the first of these precautions is self-evident and for the latter two is found in the increased voltage during the charge, and particularly as it approaches completion. This would be sufficient to cause the lamps to burn out and to injure the bell. It is important that the manufacturer's directions with regard to the charging rate be closely observed. In order to be certain that this is done, the current should be measured by an accurate ammeter mounted on a panel board in the garage. The ammeter on the vehicle should never be employed for this purpose, as the vibration and road shocks to which it is subjected make this instrument inaccurate.

Starting the Charge. To start charging, the rheostat handle should be turned so as to throw all the resistance in. The switch on the panel board should be open, and the charging plug should then be inserted in its receptacle on the car. These plugs are usually made so that they can be inserted only in the proper way, and there is no danger of reversing the polarity of the current in this manner. Where not thus designated, the terminals are properly marked and care must be taken to see that the plug is correctly inserted. When the plug is in, the switch may be thrown on. Battery manufacturers supply tables showing what the starting and finishing voltages of the battery should be, as well as its final voltage; but as this will be influenced by varying conditions, such as the temperature of the battery and the age of the plates, the figures given are only approximate. Furthermore, a new battery will have a higher final voltage than an old one under the same temperature conditions, and both old and new cells will read higher with the temperature low than when it is comparatively high. In view of the foregoing, a fixed voltage cannot be considered as an accurate test in determining the completion of the charge. Instead, a maximum voltage will be found the only certain indication.

Automatic Charge-Stopping Device. Where constant attendance during charging is neither practicable nor desirable—as in the case of the owner who takes care of his own car—an automatic charge-stopping device is a great convenience. This is an attach-

ment to the Sangamo ampere-hour meter, and is much used on such installations. It consists of a solenoid-actuated trip-circuit breaker, Fig. 51, which is set in operation by the pointer of the meter when closing a circuit on arriving at the point of full charge, a point which has been fixed by the operator in advance. However, as it is necessary to put more current into a storage battery than can be obtained from it, a certain amount of overcharge must be allowed for in every case. The amount necessary will naturally depend upon the condition of the battery as influenced by its age and the treatment it has received, but it can be determined readily after a little experience. In the Sangamo differential shunt ampere-hour meter referred to, a sliding adjustment is provided for this purpose and, once set, it need not be disturbed for a considerable period unless made necessary by a change in the condition of the battery. With this adjustment made, the charging can be done by any unskilled laborer, as it is only necessary to make the charging connection and leave it. Since the circuit cannot

Fig. 51. Solenoid-Actuated Trip Circuit Breaker
Courtesy of Sangamo Electric Company, Springfield, Illinois

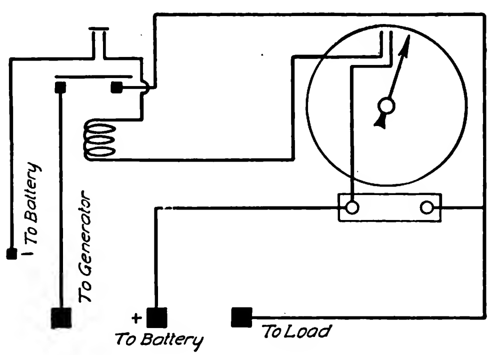


Fig. 52. Circuit Diagram of Charge-Stopping Device, Sangamo Ampere-Hour Meter

TABLE III

Temperature Correction for Specific Gravity of Electrolyte*

30° F.	40° F.	50° F.	60° F.	70° F.	80° F.	90° F.	100° F.
1.317	1.313	1.310	1.307	1.303	1.300	1.297	1.293
.12	.08	.05	.02	1.298	1.295	.92	.88
.07	.03	.00	1.297	.93	.90	.87	.83
.02	1.298	1.295	.92	.88	.85	.82	.78
1.297	.93	.90	.87	.83	.80	.77	.73
.92	.88	.85	.82	.78	.75	.72	.68
.87	.83	.80	.77	.73	.70	.67	.63
.82	.78	.75	.72	.68	.65	.62	.58
.77	.73	.70	.67	.63	.60	.57	.53
.72	.68	.65	.62	.58	.55	.52	.48
.67	.63	.60	.57	.53	.50	.47	.43
.62	.58	.55	.52	.48	.45	.42	.38
.57	.53	.50	.47	.43	.40	.37	.33
.52	.48	.45	.42	.38	.35	.32	.28
.47	.43	.40	.37	.33	.30	.27	.23
.42	.38	.35	.32	.28	.25	.22	.18
.37	.33	.30	.27	.23	.20	.17	.13
.32	.28	.25	.22	.18	.15	.12	.08
.27	.23	.20	.17	.13	.10	.07	1.203
.22	.18	.15	.12	.08	.05	1.202	.98
.17	.13	.10	.07	1.203	1.200	.97	.93
.12	.08	.05	1.202	.98	.95	.92	.88
.07	1.203	1.200	.97	.93	.90	.87	.83
1.202	.98	.95	.92	.88	.85	.82	.78
.97	.93	.90	.87	.83	.80	.77	.73
.92	.88	.85	.82	.78	.75	.72	.68
.87	.83	.80	.77	.73	.70	.67	.63
.82	.78	.75	.72	.68	.65	.62	.58
.77	.73	.70	.67	.63	.60	.57	.53
.72	.68	.65	.62	.58	.55	.52	.48
1.167	1.163	1.160	1.157	1.153	1.150	1.147	1.143

*Cushing and Smith, *Electric Vehicle Handbook.*

be broken until the predetermined number of ampere hours have been absorbed by the battery, the latter will remain connected to the mains until fully charged, so that there is no danger of either undercharging or overcharging, as may occur where the charge is simply limited by the time considered necessary. The circuit of this charge-stopping device is shown by the diagram, Fig. 52. The circuit breaker also opens the exciting circuit, so that it carries the current only for an instant.

Rated specific gravity for various stages of charge is based on a temperature of 80° F. Corrections for temperatures above and below this point may be made from Table III.

Testing Progress of Charge. Upon the completion of the charge, the rheostat handle should always be turned back before opening

the battery switch. It is essential that any voltage readings taken as a guide of the battery's condition should be noted only while the charging current is on. This applies likewise to readings during the discharge of the battery, which should be taken while the vehicle is running, as the voltage with the battery standing idle is of no value as an indication of its condition.

But the voltage alone must not be depended upon. The specific gravity of the electrolyte as well as the voltage will rise and reach a maximum as the end of the charge approaches. Specific gravity readings should therefore be taken with the hydrometer syringe provided for this purpose. This instrument consists of a glass syringe in which there is a hydrometer, Fig. 54. By inserting the point of the syringe in the venthole of a battery, it may be filled with the electrolyte, thus causing the hydrometer to float. The specific gravity of the solution may be noted and the latter replaced in the cell without any necessity for handling. Several cells in various parts of the battery should thus be tested as

Fig. 54. Syringe Hydrometer Set

Fig. 53. Acid Testing Set in Separate Parts

TABLE IV

Baumé Scale of Specific Gravities

Baume	Specific Gravity	Baume	Specific Gravity
0	1.000	18	1.141
1	1.006	19	1.150
2	1.014	20	1.160
3	1.021	21	1.169
4	1.028	22	1.178
5	1.035	23	1.188
6	1.043	24	1.198
7	1.050	25	1.208
8	1.058	26	1.218
9	1.066	27	1.228
10	1.074	28	1.239
11	1.082	29	1.250
12	1.090	30	1.260
13	1.098	31	1.271
14	1.106	32	1.283
15	1.115	33	1.294
16	1.124	34	1.306
17	1.132	35	1.318

a check of the voltage. An older form of testing set is shown in Fig. 53. When fully charged, the specific gravity of the electrolyte should be between 1.270 and 1.280. Because of the spraying through the ventholes when the cells are gassing freely, and the loss by sloppage and evaporation, there is a gradual lowering of the specific gravity. It may be permitted to run as low as 1.250 when fully charged. It is not necessary to make both the voltage and specific gravity tests every time the battery is charged, but they should be carried out at least once a fortnight, when all the cells should be tested to determine if they are in uniform condition.

Baumé Scale. Hydrometers are often graduated according to the Baumé scale. The Baumé scale for liquids heavier than water is based upon the following equation:

$$\text{Sp. Gr.} = \frac{145}{145 - \text{Baumé degrees}} \text{ at } 60° \text{ F.}$$

Table IV gives the corresponding specific gravities and Baumé degrees.

Should the specific gravity of some of the cells be lower than the remainder of the battery, the low cells should first be charged separately at a low rate. If the specific gravity increases, it is an indication that the cell had been discharged to a lower point than the

others and simply needed additional charging. Should this not be the case, and if neither the specific gravity increases nor the temperature rises rapidly during the charge, it indicates that the gravity of the electrolyte has been lowered by the addition of water to compensate for loss due to leakage or similar cause. The cell should accordingly be examined for the cause of the loss by sawing through the connections or straps and removing the cell from the battery. If the jar is found to be broken or cracked, a new one should be substituted, new electrolyte of the same specific gravity as that of the remaining cells put in, and the cell fully charged. The specific gravity of the electrolyte should then correspond with that in the other cells. If the loss of electrolyte has been due merely to slopping over, electrolyte should be added and the whole tested for the right specific gravity. The outside of the jar and the tray beneath it should be thoroughly cleaned, and the cell put back and its connections burned into place, care of course being taken to have positive and negative plates connected as they were before removal.

As the electrolyte of the Edison cell does not vary with its state of charge, the specific gravity test cannot be employed, the voltmeter affording an accurate indication of the condition of the cells. Electrolyte cannot be lost from the Edison cell as it is sealed in, but there is a certain amount of loss by evaporation which must be replaced with distilled water.

Electrolyte. Manufacturers of storage batteries usually recommend that small users purchase their supplies of electrolyte from them in order to be certain of its purity and specific gravity. Where this is not convenient, the owner of the electric vehicle may mix his own solution. This should consist of *distilled water* and *pure sulphuric acid* in the proportion by volume of one part acid to four and three-quarter parts of water for electrolyte of 1.200 specific gravity, or one part acid to three of water for 1.275. A glass, porcelain, or earthenware vessel must be employed for mixing the solution, and the acid must be poured very slowly into the water. Never pour water into acid, for while the effect of slowly adding acid to water is negligible, the adding of water to concentrated acid is accompanied by violent chemical action and an evolution of heat will usually break the containing vessel and always cause a dangerous spattering of the acid.

The sulphuric acid should be chemically pure, and, wherever possible, distilled water should be used. If this is not obtainable, the use of clean rain water is recommended as being likely to contain less impurities than any other. The keeping of the electrolyte free from impurities is a matter of the utmost importance and one that must ever be borne in mind. All dirt and foreign substances, both liquid and solid, must be rigidly excluded. A piece of iron in the shape of a stray tack, small nut, or wire may fall into a cell and ruin it before its presence is discovered. The presence of iron will be indicated by the electrolyte and the positive plate becoming a dirty yellow color. Some other impurities also make their presence readily known, for instance, chlorine will give off fumes that are easily recognizable by their disagreeable odor.

Whenever such a condition is discovered, the only remedy is to dismantle the cell immediately, regardless of the state of charge or discharge it may be in. Discard the electrolyte and the wood separators, and thoroughly rinse in running water all parts of the cell, such as the jar, rubber separators, and both of the elements; the latter should be washed separately. Reassemble with new electrolyte of the same specific gravity as that discarded, and new wood separators. Charge the cell and discharge fully several times. After the last of these discharges and before recharging, take the cell apart a second time, again discarding the electrolyte, rinsing the parts of the cell in running water and soaking the wood separators in several changes of water. The cell may now be reassembled permanently with electrolyte of 1.200 specific gravity. It should be given a long charge before being put into service again. Care must be taken not to allow the negative elements to become dry at any time during this operation, in fact, it is better to keep both sets of plates under water until reassembled.

Dangers of Overcharging. To revert to the subject of charging in general, too much cannot be said regarding the evils of giving an excessive overcharge, an abuse which may occur in two ways: charging the battery for too long a time, and charging too frequently. The commoner of these—that of charging too long a time—is easy to avoid. The other is not so apparent, and is the result of a practice which is apt to be indulged in by the uninitiated owner of an electric car, being due to a desire to have it always ready to run

its available mileage. This is the custom of charging too frequently. For instance, if the capacity of the battery will run the car 40 miles on a charge, and but 5 miles are covered and a short charge given, then 10 miles are covered, and a second charge, followed by a second and third installment of 10 miles with a charge between each and after the last, it is obvious that but 35 miles have been covered altogether, but the battery has been charged four times. This is three times more than was necessary under the circumstances, besides which the available radius was not covered, so that the battery would really not have been discharged had the entire distance in question been covered without recharging. The greatest wear on the plates of a battery occurs during the final part of a charge, so that the oftener the battery is charged the shorter its life will be. As stated at the outset, the life of the very best cell made is measured by a certain number of discharges, but this is on the assumption that it is not recharged until actually discharged each time. Where a vehicle is employed for short runs, such as those mentioned, the capacity of the battery will not give as great a mileage as if the entire distance were covered in one run. When covering but a few miles in daily service, it is not advisable to recharge until between 50 and 75 per cent of its capacity has been exhausted.

Where it is desired to use the car within a comparatively short time after the battery has been exhausted, it is permissible to hurry the charge within certain limits by using a higher rate than normal. This should be employed only at the start of the charge and should be reduced immediately the cells begin to "gas." When the "finishing" voltage has been reached, the charge should be reduced to the normal starting charge, the remainder of the charge being carried out as if the battery had been started on the latter. Great injury may be done to the plates by "pounding" a nearly full battery at a high rate of charge. The foregoing precautions do not apply to the Edison cell.

Time Required to Charge. The time required for charging will naturally depend upon the extent of the preceding discharge. If the latter has been two-thirds of the rated capacity of the battery, the usual pleasure car will require about three hours at the starting rate and one and a half to two hours at the finishing rate. In other words,

about 10 to 15 per cent in excess of the amount discharged is usual. At least once a fortnight, a prolonged charge should be given by continuing the charge for one hour after the specific gravity of the electrolyte has ceased to rise. Where a vehicle is maintained by its owner in a small private garage, and is used more or less during the day, it will be found a great convenience to do most of the charging during the night, and for this purpose the mercury arc rectifier, described in the chapter on "Methods of Charging", will be found a great help. Where direct-current service is available at 110, 220, or 500 volts, such an adjunct will naturally not be necessary. In over-night charging, precautions must be observed to prevent an excessive overcharge. To do this, a careful estimate of the current required to fully charge the battery must be made before putting it on charge, and the rate adjusted accordingly. If 12 hours be available for charging and 84 ampere hours are necessary, the average rate of charge must be 7 amperes. Should the time be only 9 hours, as where a vehicle has been used in the evening and is wanted again early in the morning, the average rate would be slightly more than 9 amperes. Where 72 ampere hours are required in 9 hours, the rate would be 8 amperes, and so on. The rate, however, will also depend to some extent on the voltage of the charging circuit, in charging from a source with constant voltage, the rate into the battery will fall as the charge progresses. This is also the case where the charging is done with the aid of a mercury arc rectifier. After the charge is ended, the voltage will drop immediately when the battery is disconnected.

Charging an Edison Battery. The charging rates of Edison cells are based on a voltage of 1.85 volts per cell, so that the potential required to charge a battery of this type is as follows:

Number of Cells	Volts Across Cells
10	18.5
20	37.0
30	55.5
40	74.0
50	92.5
60	111.0
70	130.0
80	148.0
90	167.0
100	185.0

These voltages are just sufficient to charge the number of cells in question at the normal rate during the end of the charge, as the alkaline cell increases its voltage during charge in the same manner as the lead cell, there being also a similar drop in voltage when the charging current is shut off. While a slight reduction in voltage from the potentials given will not materially affect the charge, allowance should be made for what is required in every case, if necessary, by charging the battery in series multiple.

Owing to their construction the Edison cells are capable of being *boosted* at high rates when it is necessary to charge quickly, but the temperature must not be allowed to exceed 115° F. The following are the boosting rates recommended by the makers as the result of experience:

5 minutes at 5 times the normal rate
15 minutes at 4 times the normal rate
30 minutes at 3 times the normal rate
60 minutes at 2 times the normal rate

The sizes, capacities, charge and discharge rates of the Edison cells are as follows:

Type A-4	A-5	A-6	A-8	A-10	A-12
Capacity 150 ampere hours	187.5	225	300	375	450
Normal charge / Normal discharge 30	37.5	45	60	75	90

They are capable of discharge rates in excess of these figures in the same proportion as the boosting rates.

BOOSTING

Advantages of Boosting. The term "boosting" as applied to electric-vehicle batteries may be defined as "auxiliary charging", and must not be confused with its use in connection with the charging of large stationary batteries. As the lead-plate cell becomes completely charged, its voltage rises to 2.5 volts per cell, which for the 55 cells required to deliver current at 110 volts, would mean a potential of 137.5 volts, or an increase of more than 20 per cent over that of the generator. The latter, not only being a constant potential dynamo, but also being called upon to deliver current for other service while charging the battery, it is necessary to raise the voltage

of the charging current in order that it may exceed that of the battery without, at the same time, altering the output of the generator. For this purpose, what is known as a "booster" is employed, i.e., a motor-generator which imposes a higher voltage on the charging current than that at which it is produced by the main generator.

In the case of a vehicle battery, it usually implies a partial charge given in a comparatively short time and at current rates considerably higher than normal, and it represents a practice which has had an important influence on the use of the electric vehicle for commercial purposes. For example, many of New York's several thousand electric trucks of three to five tons' capacity are now sent on trips that were considered beyond the range of the electric only a few years ago, as it is not unusual for five-ton brewery trucks to make a fifty-to-sixty-mile day's run in one round trip from the plant. How this is accomplished with batteries whose normal output only suffices to run the car forty miles on a charge will be apparent from a consideration of the practice of "boosting" the battery, which is usually carried out during the noon hour.

Regulation of Boosting Charge. Stress has already been laid on the fact that overcharging at high rates is injurious to the lead battery, and is the one thing to be most carefully avoided. However, the improved forms of vehicle batteries now in use have considerable ability to absorb current at high rates under proper conditions. The only factors which act injuriously in high-rate charging are *gassing* and *heating*, and these appear only when the battery is receiving more current than the plates can utilize. Therefore, any current rate which the cells will absorb without gassing is not injurious, and it is upon this principle that boosting is applied.

Possible Safe Charging Rates. The more nearly discharged a battery is the higher charging rate it can take, and by starting the charge at a high rate and tapering to a low rate at the end, a large proportion of the discharge can be replaced in a very short time. Table V gives the additional battery capacity which can be obtained by constant potential boosts with the battery in different states of discharge.

TABLE V

Potential Boosts at Different States of Discharge

Battery Charge	20-Minute Boost Increase	40-Minute Boost Increase	60-Minute Boost Increase
Battery fully discharged	22%	38%	50%
Battery three-quarters discharged	19%	33%	42%
Battery one-half discharged	15%	26%	32%
Battery one-quarter discharged	10%	16%	20%

Expressed in terms of mileage, this would mean that a car, after having given forty miles on a complete discharge, could have its battery boosted as follows:

In 20 minutes so as to give 9 miles additional
In 40 minutes so as to give 15 miles additional
In 60 minutes so as to give 20 miles additional

Thus, by charging during the noon hour, 140 per cent of the battery capacity is obtained in one day, bad weather conditions particularly representing conditions under which it is advantageous to be able to boost the battery.

Methods of Boosting. There are several methods by which boosting can be practically carried out, and the method chosen depends upon the available charging facilities.

Constant-Potential Method. The ordinary incandescent lighting circuit is supplied by a constant-potential generator, i.e., the voltage does not vary regardless of the current utilized within the limits of the capacity of the generator. Where conditions permit, this is the best method because it is entirely automatic and requires little attention. It is applicable wherever there is available a voltage of about 2.3 volts per cell of battery—say 110 volts for 48 cells—and the charging equipment and wiring have sufficient capacity to carry current up to four or five times the usual charging rate. A voltage higher than 2.3 volts per cell can be reduced by having a set of counter-e.m.f. cells figured at 3 volts per cell, which are always put in series with the battery when it is boosted. This is a special type of cell designed for this purpose. Thus if the line voltage is 110 and the battery consists of 40 cells, a reduction of 18 volts will be necessary, and six of the counter-e.m.f. cells will be required.

With the charging voltage thus fixed at 2.3 volts per cell, a battery in any state of discharge can be put on charge and will receive in a short time a large proportion of the discharge which has been utilized. The current input will taper automatically from a high rate at the start to a low rate at the finish, and no attention or adjustment is required. The cells will not reach the *free gassing* point or, under normal conditions, a high temperature and, therefore, no harm will result from their being inadvertently left on charge.

Approximate Constant-Potential Method. This is employed with a fixed resistance in series with the battery; and when the time available for boosting is one hour or less, the following method is often the simplest. Connect a rheostat in series with the battery and adjust the resistance so that the voltage across the *battery terminals* corresponds to that given as follows for the approximate number of cells.

Number of Cells	Voltage at Battery Terminals
48	110
44	98
42	92
40	86
38	80

The circuit can then be left without attention for an hour or so, and the current will taper off as the voltage of the battery rises. The table is figured for a line voltage of $\frac{110}{120}$, and the voltages given are too high for a boost of more than one hour's duration.

Constant-Current Method. In some cases it is more convenient to boost at a constant rate of current, and, as there is usually a limited time available, it is desirable to know under any given conditions what rate is safe. This may easily be determined as follows:

$$\text{Charging current (amperes)} = \frac{\text{ampere hours already discharged}}{1 + (\text{hours available for boosting})}$$

This gives the maximum current which can be employed for the time specified without the cells reaching the gassing point. The method is most conveniently employed where the car is equipped with an ampere-hour meter. For example, 100 ampere hours have

TABLE VI

Boosting Rates*

Ampere Hours Discharged	Time Available for Boosting							
	¼ hour	½ hour	¾ hour	1 hour	1¼ hours	1½ hours	1¾ hours	2 hours
	Amperes	Amperes	Amperes	Amperes	Amperes	Amperes	Amperes	Amperes
10	8	6	5	5	4	4	3	3
20	16	13	11	10	9	8	7	6
30	24	20	17	15	13	12	11	10
40	32	26	23	20	18	16	14	13
50	40	33	28	25	22	20	18	16
60	48	40	34	30	26	24	22	20
70	56	46	40	35	31	28	25	23
80	64	53	45	40	35	32	29	27
90	72	60	51	45	40	36	33	30
100	80	66	57	50	44	40	36	33
110	88	73	63	55	49	44	40	37
120	96	80	68	60	53	48	43	40
130	104	87	74	65	58	52	47	43
140	112	93	80	70	62	56	51	47
150	120	100	86	75	67	60	54	50
160	128	106	91	80	71	64	58	53
170	136	113	97	85	75	68	62	57
180	144	120	103	90	80	72	65	60
190	152	127	108	95	84	76	69	63
200	160	133	114	100	89	80	73	67
210	168	140	120	105	93	84	76	70
220	176	147	126	110	98	88	80	73
230	184	153	131	115	102	92	84	77
240	192	160	137	120	106	96	87	80
250	200	167	143	125	111	100	91	83

*Courtesy of Electric Storage Battery Company.

Explanation. In the left-hand column find the figure nearest to the ampere hours discharged from the battery; follow across to the column headed by the available time. The figure at this intersection is the current to be used.

Example. Ampere-hour meter reading, 103 ampere hours discharged; time available for boosting, one hour. Start at 100 in the left-hand column; follow across to the column headed 1 hour and find 50, which is the current to be used.

been discharged and there is one hour available for boosting. Then

$$\text{Charging current} = \frac{100}{1+1} = 50 \text{ amperes}$$

In general, this method will not put in as much charge in a given time as the constant-potential method, and the current must not be continued *beyond the time for which the rate is figured,* as injurious gassing and heating will result. When a considerable

period is available for boosting, and it is convenient to regulate the current at intervals, a greater amount of charge is possible by dividing the time into several periods and regulating the amount of current for each period separately. It will usually be found that one of the methods outlined will be available, but to obtain the advantages of boosting without injury to the battery, gassing must be avoided and the temperature of the cells kept below 110° F.

Table VI is based upon the above formula and saves the necessity of making calculations.

Importance of Careful Attention to Battery. The battery is naturally the chief factor in any electric automobile and, as its initial cost is no small fraction of the total cost of the vehicle, its proper maintenance is a matter of economy no less than of good service. More so than any other piece of electrical apparatus, a storage battery has a definitely determined life. Regardless of the care given it, the active period of service of which it is capable may be expressed as a certain number of discharges. By properly looking after it, this number may be realized, and a greater percentage of the energy put into it taken advantage of. In other words, its life will not only be longer, but its efficiency much higher during that period as the result of proper care.

SOME SOURCES OF POWER LOSS

As the power of the electric vehicle is closely limited by the capacity of the battery it carries, it is absolutely essential that every part of the mechanism be kept in good running order so that none of the power may be wasted. Whether the machine is considered as a whole, or each component is treated separately, the electric vehicle is about as simple as it possibly could be. But the number of places at which power losses may occur will greatly surprise the uninitiated owner when he comes to look into the subject. It is nothing unusual for the purchaser of an electric vehicle to write the maker a year or so after he has bought it that while the car ran perfectly satisfactory at first, its mileage has now been very much reduced. He has followed instructions implicitly, the battery has been well looked after, and, according to all indications, it is in as good

condition as ever it was, but it is impossible to obtain anything like the rated mileage from a full charge of the battery. A little investigation will show that, in the majority of cases, the owner, who has not had the advantage of a mechanical training, has become so impressed with the great importance of properly maintaining the electrical end of the car that he has disregarded its mechanical efficiency entirely.

Non-Alignment of Steering Wheels. One of the most prolific sources of power losses, and one of the last to be suspected, is non-alignment of the wheels. A chance blow in drawing up alongside a curb is sometimes sufficient to make one of the front wheels "toe in" slightly. The fault is not noticed and may be aggravated by subsequent blows at the same spot, or on the other wheel. This may cause the bearings to bind to a certain degree and also to impose a heavy load on the motor by the new angle which the tires make with the road surface. It is difficult for the average layman to appreciate how great an increase in the load such a seemingly trivial fault as this may create, and it can only be realized to a certainty by keeping a record of the ammeter readings at all of the speeds under normal conditions. Just how much current is required to start and to mount various grades should be noted. As the service of an electric vehicle is chiefly confined to urban travel and covers practically the same routes day after day, it is possible to keep a close check on current consumption by noting how far the ammeter needle travels over the dial in running on the level and in mounting grades that have to be climbed frequently. Small increases in the current required to do the same work at different times would then be readily apparent, and as the malady is imposing an extra drain on the battery, which is simply a waste of energy, its cause should be looked for and remedied.

The electric vehicle is a power-measuring machine without an equal, and the driver who has familiarized himself with the performance of his car under favorable conditions should be able readily to detect the presence of trouble by the increased current consumption and the correspondingly decreased mileage per charge. The causes may be electrical as well as mechanical, and where a car has not been properly looked after, it is more than likely that the falling off in the available radius on a single charge will be traceable to an

accumulation of causes small in themselves, but of considerable importance in the aggregate. Disalignment of the front wheels may sometimes be due to the steering gear—that is, the connecting rod which serves to keep these wheels parallel—working out of adjustment. Unless they are perfectly aligned, they not only make more current necessary to propel the vehicle, but they also serve to wear out the front tires more rapidly than would otherwise be the case. Sagging of the rear axle, which was not an uncommon fault in earlier years, but which is now rare, will produce similar conditions at the rear wheels and, as the entire power of the car is utilized at this point, the result is just that much worse.

Worn Chains and Sprockets. Next in the order of importance to badly aligned driving or steering wheels from a mechanical point of view, comes a worn driving chain. This naturally applies to the chains employed for either of the reductions in motor speed. It is likewise equally true of the sprockets, but a worn sprocket is practically always the result of the continued use of an old chain. The latter is allowed to wear to a point where its pitch is greater than that of the teeth of the sprocket, and, in consequence, the chain shows a constant tendency to ride the teeth of the sprocket instead of fitting snugly between them, as should be the case. This tightens the chain and imposes a greatly added load upon it and the sprocket, with the result that the teeth of the latter are also soon worn out of pitch. When this occurs, the only remedy lies in the replacement of both chains and sprockets, as the fitting of a new chain on a worn sprocket aggravates the evil and causes the new chain to wear to a point of uselessness in a very short time. The best preventive is to watch the driving chains for such conditions and to replace a chain as soon as it gives any indication of mounting the teeth instead of running smoothly.

These instructions apply only to pleasure models antedating 1913-14, as practically all models are now made with the shaft drive using a bevel gear or worm; but there are thousands of the older chain-driven cars in service, the electric having a much longer effective life than the gasoline car.

Non-Alignment of Axles. On all electric cars, whether they be of the chain- or shaft-driven variety, it will be found that some means are provided for aligning the rear axle. These take the form

of *distance* or *radius rods*, attached through the medium of a hinge joint to the axle and some form of pivot joint at the countershaft, this construction having been referred to in connection with the description of the transmission of a double chain-driven car. Although effective means of locking these rods are provided, they are subjected to constant vibration and jolting and sooner or later will require attention. It will be apparent that if one is adjusted so as to be somewhat shorter than the other, an excessive fraction of the load will be imposed on the driving chain on the short side. This will also place a very heavy strain on the differential or balance gear, and a greatly added amount of power will be required to drive the car. The importance of accurately adjusting the distance rods so that the rear axle will be at right angles with the frame and of maintaining it in that condition may accordingly be appreciated.

Dry Bearings. It would appear almost superfluous to mention lack of oil as a mechanical source of power loss, but many electric vehicle owners seldom attach sufficient importance to the necessity for oiling the moving parts. It is a popular fallacy, quite generally indulged in, that the anti-friction bearing is a mechanical device that requires no lubrication. Ball bearings do call for less attention in this direction than any other. They need very little oil, and at much longer intervals than a plain bearing, but they cannot render efficient service without some lubricant. In fact, it is this very ability to stand an uncommon amount of abuse that seems to have earned for the ball bearing its popular reputation for ability to run quite as well whether it is dry or oiled. The lubricant not only serves the same end that it does in any bearing—that of reducing friction, but it also acts as a preventive of rust—the greatest enemy of the ball bearing; and as these bearings are rather expensive replacements, it pays to avoid this by regular oiling at least once a month. Only the best grade of light machine oil should be employed, or a thin-bodied and highly-refined vaseline with which the bearing may be packed. It is quite essential that the lubricant should be entirely free from acid, which would attack the highly polished surfaces of the balls and races and destroy the efficiency of the bearing. The electric-vehicle user's chief safeguard against this is to confine his purchases to brands recommended by the manufacturer of the car. Where the presence of acid is suspected, a simple test may be made by

dipping a small piece of cotton waste in the lubricant and then wrapping it around a piece of polished steel. This should be placed in the sun and examined at the end of a week or more. If the lubricant contains acid, there will be traces of its etching effect on the polished surfaces and it is useless. Oil that is entirely free from acid will not affect the most highly polished surface.

Wheels and axles out of alignment, worn chains and sprockets, improperly adjusted brakes, which may be dragging, and neglected bearings sum up the chief mechanical sources of power loss.

It is quite as important, however, that losses of electric power be guarded against, as they interfere with the efficient utilization of the energy stored in the batteries and decrease the available mileage on a charge, regardless of the condition of the mechanism. Vibration will prove the undoing of almost anything in the course of time, and, while every precaution is taken by the manufacturer to provide durable and permanent connections, it seems practically impossible to provide a form of terminal that will be absolutely proof against this influence and still permit of being disconnected conveniently when required. Air interposes a very high resistance in a circuit, and but a slight amount of looseness in a connection creates an air gap that must be bridged by the current in order to complete the circuit. This causes *arcing*, or a flashing of the current across the gap, which is destructive of the terminals and is not infrequently responsible for the ignition of adjacent material. As will be apparent from the wiring diagram given, there are quite a number of such connections, and going over them systematically at regular intervals is the only way to guard against current losses from this source.

Brushes and Commutator. The brushes and commutator are the only parts of the electric motor that are subject to wear, and the life of the commutator is naturally equivalent to that of several sets of brushes, so that the latter constitute practically the sole item to be looked after in connection with the motor. They are either plain blocks of carbon, or carbon with fine copper wire embedded in it, and are held against the commutator by springs. To examine their condition closely, the housing should be removed, the rear axle jacked up, and the motor run on the first speed. No attempt should be made to run it on any of the other speeds when in this condition, nor should it be run any longer than necessary. This does not

exactly simulate actual driving conditions as, with the wheels off the ground, practically no load is imposed on the motor and, while the latter may spark badly under load, it will frequently give little indication of this form of trouble when running light.

If the brushes have been sparking badly in actual service there will be certain signs of this in the shape of the blackened commutator bars. They should be wiped clean and, if any oil has leaked on to them from the bearing, all traces of it should be removed. If this does not suffice to remove the blackened appearance, the sparking has been such as to burn the copper, and this blackened surface should be removed with the aid of a piece of very fine sandpaper held against the commutator while it is turning slowly. Never use emery cloth for this purpose, as the abrasive material employed in its manufacture is of a metallic nature, and not only tends to embed itself in the insulation between the bars, but, once there, serves as a conductor and may short-circuit some of the armature coils, resulting in serious damage to the motor. If the brushes merely appear to be glazed but still make good contact all over the bearing surface, the latter may be rubbed with the sandpaper as well. If they have worn to a point where the contact is not good, new brushes should be substituted, and it would be well for the owner of the electric vehicle who is not familiar with the motor, to have an experienced person put them in for him the first time—every time, in fact, unless he is perfectly sure of his own ability in this line. A set of brushes will seldom, if ever, need replacement more than once during an entire season.

For instructions covering seating of brushes, testing springs, and the like, refer to sections on these faults in the article on Starting Motors and Lighting Generators.

Armature Troubles. When the housing is off, the brush connections and other motor connections should be inspected for looseness or other faults. Instructions for locating grounds, short-circuits, or open circuits in the armature and field windings are given in connection with the articles on Starting and Lighting Systems.

The armature is supported on annular ball bearings in the majority of cases, and while these bearings require little attention, they should be packed with vaseline as already directed, when needing

lubrication. Oil should not be used as it will flow out on to the commutator at one end or the armature windings at the other.

Miscellaneous. In speaking of connections, those at the battery are included and they should be inspected as well. The connections between the different cells are usually made by burning the lead-strap terminals together, though some have bolted connections, and these may jar loose; but the various groups are connected to one another and to the remaining apparatus, and these terminals are probably more apt to give trouble than some of the others, as it is nothing unusual to remove the battery at times and sufficient care is not always exercised to have the connections solidly fast.

The loss of electrical energy, due to undercharged and short-circuited cells in the battery, has been treated in detail in connection with the care of the battery.

Tires are, without doubt, one of the greatest sources of power loss on the electric vehicle, and it is one that mystifies the uninitiated exceedingly. This matter is gone into at length in connection with tire equipment.

TIRES AND MILEAGE

Relation of Tires to Mileage. It will appear odd and somewhat inexplicable at first sight that these two headings should be included in the same chapter, for the average man thinks that the only thing which has any direct influence on the mileage of the car is the amount of energy the battery is capable of giving forth. As is pointed out under "Sources of Power Loss", there are many other factors that affect the available radius of the car more or less indirectly. Tires are not included among these indirect sources, as the tire equipment has a *most direct* and, therefore, a most important bearing on the distance the electric car is capable of traveling on a single charge of the battery. The gasoline machine is endowed with such a liberal surplus of driving power that the loss occasioned by tires represents but an insignificant fraction of the whole; in other words, is a totally negligible factor. Had it not been for extensive experiments carried out in connection with the electric automobile, the importance of these losses would not have been definitely known.

When all the points which contribute to both the electrical and mechanical efficiency of the car have been carefully maintained in

proper working order, and still both the speed and total capacity of the battery fail to respond, the cause of the trouble may be summed up in a single word—"tires." For tires constitute the most important element in the determination of mileage and, though that fact is seldom, if ever, mentioned in connection with accounts of phenomenal mileages made on a single charge, they are the chief controlling factor. The tires usually employed for such "stunts" are specially made for the purpose and are not adapted to ordinary service. They have extremely thin walls, with the thread of the fabric reinforcement running continuously round the tread of the tire in the same direction, and are not only very likely to puncture on slight provocation, but are far from durable. The expense of employing such tires regularly would be prohibitive, particularly as they are very difficult to repair when punctured.

Kinds of Tires. *Pneumatic.* On the gasoline car, in view of the great weights and high speeds, it is solely a question of being able to make the pneumatic tire sufficiently strong to stand the unusually severe stresses to which it is subjected. To accomplish this end, the fabric structure forming the foundation of the shoe, or outer envelope of the tire, is made of various layers of heavy canvas placed at angles to one another and solidly vulcanized together. This construction makes an extremely stiff wall, as is evidenced by the difficulty in forcing a clincher type of tire on to the rim. Such a tire will yield to the minimum degree under the weight of the car or road obstacles when inflated to the proper pressure. In consequence, it absorbs considerable power. This loss is still further increased by the use of chains, studs, or similar anti-skid devices. Tests made on the recording dynamometer of the Automobile Club of America in New York City have shown that some forms of non-skid treads, particularly those employing heavy steel studs embedded in thick leather, absorbed as much as 5 horsepower per wheel to drive them. Tests showing 2 to 2½ horsepower per wheel were not uncommon, and in but few instances did the loss drop below 1 horsepower per driving wheel, regardless of the type of tire employed.

It would be manifestly out of the question to expect much in the way of mileage from an electric vehicle if handicapped in this

manner. Non-skid devices of any kind are rarely seen on electric automobiles for this reason, about the only occasion when they are in evidence being in winter, when they are actually required on ice or slushy pavements to afford sufficient traction. For electric service a structure is required in which the fabric foundation is so constituted as to be able to adapt itself most readily to the distortion caused by being pressed out flat on its contact area with the road.

Solid. Viewed from one aspect, the electric has an advantage over the gasoline car. Owing to its greatly reduced speed, the owner of an electric finds the solid-rubber tire a practical option. Naturally, there can be no comparison between the riding qualities of a solid and a pneumatic tire, but as most electric-vehicle work is over smoothly paved streets, and the reasonable driver should never take obstructions except at a greatly reduced speed, the solid tire provides an amount of comfort out of proportion to its greatly reduced cost as compared with the pneumatic. The mileage radius possible with a good solid tire is about the same as that possible with the standard fabric type of pneumatic usually referred to by the electric-vehicle manufacturer as a "gasoline" type of tire, with the advantage in favor of the former in that it is free from puncture.

Test Curves. An extensive investigation has been made of the subject of tires in the past few years and considerable data compiled. Herewith is given a series of curves prepared by the builders of the Rauch and Lang electrics which will suffice to reveal the great differences in tires where the question of mileage is concerned, Fig. 78. The curves show that of the solid types experimented with the Motz tire rendered the best performance. On referring to the chart, it will be apparent that the showing of the tire in question is somewhat more uniform than the Diamond pneumatic type. At the high limit of the range is to be found the Palmer cord tire, which is a single-tube type of pneumatic with thread fabric. Bearing in mind the fact that increasing speed means a corresponding reduction in the mileage, the application of the chart is simple. Taking the Palmer tire just referred to as an example, select in the vertical column at the left marked "miles per hour," the rate at which the car is to travel. Trace

this along the horizontal line representing the speed, to the right until it intersects the characteristic curve of the tire in question. At that point, rise perpendicularly to the point where the vertical line meets the top of the chart, which is divided into sections giving total mileage, by increments of 10 miles. For instance, suppose it be desired to run a car at 15 miles an hour on Palmer cord tires. Tracing the 15-mile line to the right, it will be found to intersect the Palmer-tire curve at the vertical line corresponding to 100 miles. A striking example of the manner in which mileage increases with reduced speed may be seen by tracing the 12½-mile

Fig. 78. Curves Showing Tests of Various Tires Made by Rauch and Lang Carriage Company

line to the right until it intersects the Palmer curve. It gives a total mileage of 123, or an increase of 23 per cent in the distance covered for a decrease of but 2½ miles per hour in the speed. By making a further reduction to 10 miles an hour, 130 miles could be covered on a charge. This, of course, is not due to any characteristic of the tire, but to the fact that the lower the discharge rate the greater the capacity of the battery, the phenomenal mileages given being the result of employing a tire that presents the minimum of resistance to bending.

New Tire Equipment. A little study of the foregoing will serve to reveal one of the most prolific causes of complaint on the

part of uninitiated owners of electric vehicles. After wearing out one or two tires in service, they instruct the garagemen to put "new ones" in their place, or they renew the old ones by purchasing in the open market themselves. Unless informed as to the purpose for which the tires are needed, both the garagemen and the tire salesman are more than apt to supply a gasoline type of tire. A distinct falling off in the mileage radius of the car is at once noticeable, particularly if the owner has been in the habit of making use of the higher speeds. The cause is apparently inexplicable, and the result is a complaint to the manufacturer that something has gone wrong or that the car is not fulfilling the promises made for it, when, as a matter of fact, greater care should have been taken to maintain the tire equipment the same throughout.

Improper Inflation. Tires have been previously mentioned as one of the sources of power loss, and the foregoing serves to explain to a great degree why this is so. An item of considerable importance in the treatment of tires, which has not been referred to, is improper inflation. A soft tire naturally consumes more power to drive it because of the increased friction due to the greater area of the tire in contact with the ground. Such a condition is detrimental to the tire itself as it increases the amount of wear and the danger of rim cuts.

If the tire be too soft, the weight of the car will cause it to spread unduly at the point of contact with the road and this condition will be immediately noticeable. On the other hand, when the tire is pumped up too hard, the tire will stand just as if it were bearing no load. Such a condition obviously places too great a strain on both the fabric and the rubber, and is frequently the cause of tire failures that are usually assigned to a totally different reason. With its ordinary load of passengers, the electric should only cause a slight flattening of the tires at the tread, experiment showing that the best results are obtained when the increase in the width of the tire is about 20 to 25 per cent, that is, a 3-inch tire when properly inflated should measure approximately $3\frac{3}{8}$ inches across its horizontal diameter at the part in contact with the road. Of course, the surest method of avoiding improper inflation is a tire pressure gage.

ELECTRIC INDICATING INSTRUMENTS AND THEIR USES

Volt-Ammeter. With an electric, it is important to watch the volt-ammeter. An example of this type of combined instrument is shown by the accompanying illustration, Fig. 79. It will be noted that the indicating needle of the ammeter does not go to the end of its scale, but reads both ways, the scale to the left hand being for the charging current, and that to the right for the discharging current. These instruments are manufactured in various forms, one type very much in use having the voltmeter and ammeter

Fig. 79. General Electric Volt-Ammeter

scales parallel in a vertical plane. Some also have the voltmeter scale so divided that the reading of the individual cells may be taken.

By becoming familiar with the readings of the instrument and by realizing their significance, the driver of an electric automobile is in a position not only to judge whether the battery is giving the proper service, but he also has an accurate gage on the condition of the running gear and transmission of the vehicle itself. The instrument is capable, therefore, of giving ample warning by its deflections of any weakness, electrical or mechanical.

Ampere-Hour Meter. While the volt-ammeter affords a constant indication of the working of the battery, as well as the effi-

ciency of the transmission, and is accordingly indispensable, it does not permit of the direct reading of the state of charge nor indicate off-hand how much of the energy has been utilized and how much remains available at any given time. For this purpose the Sangamo ampere-hour meter has been developed and generally adopted by the builders of both pleasure and commercial electric cars.

Method of Use. To keep the battery plates in good working condition, it is necessary to give the battery a certain amount of charge, so that under normal conditions more ampere hours must be put into the battery than can be taken out of it. This difference is the overcharge, and it must be taken into account in figuring the number of ampere hours in a battery available for useful work. Since the only information desired by the driver is how much energy can be taken from the battery, the Sangamo ampere-hour meter is designed to compensate for the overcharge, and indicates at all times the current available without the necessity of resetting the pointer every time the battery is charged. This is accomplished by means of a differential shunt, as shown by the diagram, Fig. 80. Two shunts are employed, and the relative value of their resistance is adjustable by means of the sliding connection G, so that the meter can be made to run slow on charge or fast on discharge, as desired. The usual method is to allow the meter to register less than the true amount on charge and the exact amount on discharge, the difference representing the loss in the battery, or overcharge.

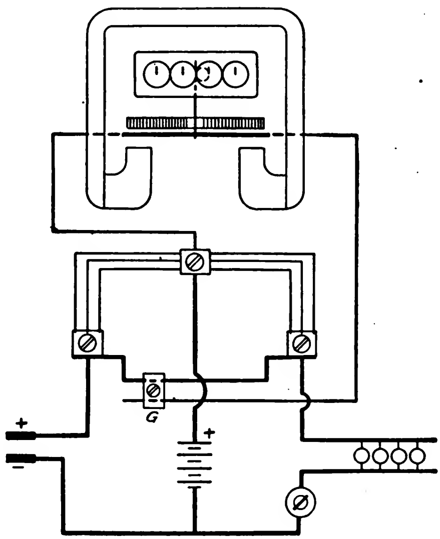


Fig. 80. Circuit Diagram of Differential Shunt Type Sangamo Ampere-Hour Meter

Readjusting the Meter. However, over long periods of use under varying conditions, the battery losses will vary and in time the meter and battery will get out of step. Therefore, it is good

practice to give the battery an extra overcharge at stated intervals and reset the meter, a simple device being provided for this purpose. Moreover, in vehicle work the batteries are frequently subjected to excessively high discharge rates and, under such conditions, the battery suffers an actual loss of capacity, which requires further compensation, as otherwise the meter will give a false indication of the number of ampere hours available. The variation in the capacity of the battery with its discharge rate is shown by the curves, Fig. 81.

In the Edison battery, the transfer of active material does not take place between the electrolyte and the plates, but from one

Fig. 81. Variation of Useful Ampere-Hour Capacity of Lead Battery with Discharge Rate

plate to the other, as in the ordinary electrolytic cell, commonly known as a primary battery. Therefore, the specific gravity of the electrolyte does not change with the state of charge and, consequently, the only direct way to measure the state of charge is with an ampere-hour meter, the hydrometer being of no use. But the loss of capacity due to high discharge rates is not a characteristic of the alkaline cell as it is with the lead type, so that an Edison battery does not require a compensated meter as just described. However, the drop in voltage of the Edison cell under high discharge rates is such that, from the user's viewpoint, the result is practically the same as with the lead-plate cell.

FORD 1921 SEDAN WITH COMPLETE EQUIPMENT AND DEMOUNTABLE RIMS

FORD CONSTRUCTION AND REPAIR

PART I

CONSTRUCTION OF PARTS

Introduction. In preparing this treatise on the construction and repair of the Ford automobile, the writer has constantly laid special emphasis upon the principle of operation of the various units and the most practical methods of repair. There is no doubt that the automobile has become one of the most widely used machines today, and necessarily it has served as an educator in mechanics. At the same time it is only wisdom—and certainly economy of both time and effort—for one to acquire his knowledge of the automobile by profiting from the experience of those who have proved their right to lay down proper practice than it is to start to do repairing with little or no knowledge of the automobile.

Familiarity with the parts and the principle of their operation makes it much easier for the mechanic or the owner to locate his troubles; if he is not acquainted with the right methods of operation or the functions of the parts, he is usually at a loss to know where he must look for the seat of the trouble.

In order to understand the operation of the different parts of the Ford car, a general description of and a detailed statement of the purpose of the various units will first be given, starting with the simple ones and progressing to the more complicated assemblies. Complete instructions for these units are given in other parts of this text where each unit is taken up in detail.

Additions to the electrical equipment on all Ford cars at the factory have opened up a hitherto unknown field to the mechanic —a field into which the Ford repair man must be equipped to enter from now on. The subject of electrical equipment has been treated very thoroughly in this volume, special emphasis being given to the methods of locating grounds, shorts, opens, etc., in the various units. Diagrams and sketches of wiring connections are also given.

Fig. 1. Plan View of the Ford Chassis

Frame. The purpose of the frame is to mount the various units in their respective order. These units are: motor, radiator, springs, steering mechanism, body, etc. The Ford frame is constructed of pressed steel, of the U section, as this type of con-

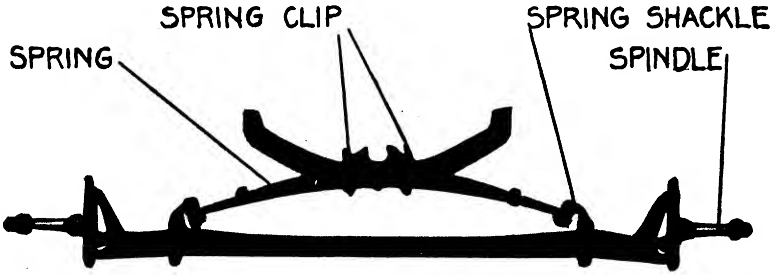


Fig. 2. Front Axle Assembly

struction gives the greatest strength for the smallest amount of steel. There are two cross members, one at each end of the frame. The purpose of these cross members is to hold the side members in place, and these members are securely fastened together with rivets. Fig. 1 is a plan view of the Ford chassis, showing the locations of the various units.

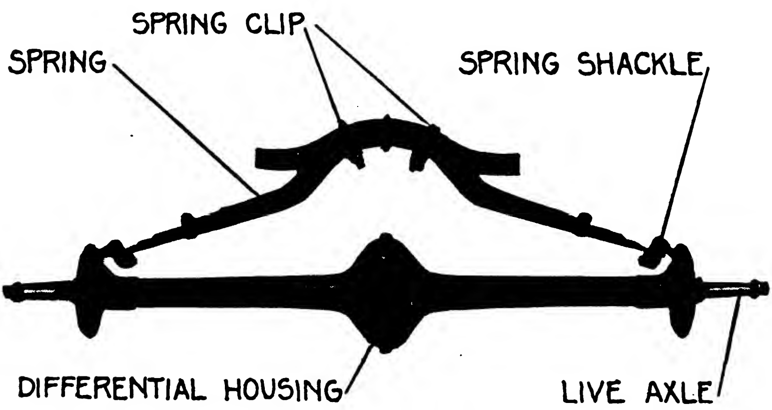


Fig. 3. Rear Axle Assembly

Front Axle. The function of the front axle, Fig. 2, is to support the weight of the front of the car through the front springs, and this axle also holds the front wheels in place by means of spindle bolts. These spindle bolts act as turning pivots for the

wheels when turning a corner. The front axle is drop forged in an I-beam section. Nearly all cars use a drop-forged axle as this

Fig. 4. Ford Unit Power Plant

construction greatly reduces the chance of flaws. It is not considered safe to use a cast-steel or a cast-iron axle.

Rear Axle. The rear-axle housing, Fig. 3, is of drawn-steel tubing. The parts are riveted together, thereby making a strong and rigid construction. These joints are also brazed to make them oil tight. The live-axle shafts and the differential gears are contained in this housing, together with suitable bearings which prevent undue wear. The driving wheels are mounted one on each rear-axle shaft. The differential equalizes the load between the two wheels.

Power Plant. The power plant, Fig. 4, is the most important unit as it transforms the gasoline into the power which drives the car. The Ford power plant is of the single-unit type as the transmission and the motor are made in one unit. A common oil case is used, although the transmission cover is a separate casting. The motor is supported on the frame at three points, this construction allowing great elasticity and preventing, to a large extent, breakage of the motor supports.

Power-Plant Accessories. There are several necessary auxiliary systems or units that must be used with every motor. These are the carburetion, ignition, lubrication, and cooling systems.

Fig. 5. Kingston Carburetor

Carburetor. The carburetor is an instrument that mixes gasoline with air in the proper proportion. The mixture is fed to the motor in variable amounts, determined by the distance the throttle is opened by the driver. Fig. 5 is a view of a Kingston Ford model carburetor.

Ignition System. The ignition system furnishes a hot electric spark in each cylinder at an exact predetermined time after the

gas vapor has been compressed and is ready to be exploded. The resulting explosion creates a high pressure on the piston and drives it down, thereby turning the crankshaft. The Ford ignition system consists of a source of current—either magneto or battery—a timer, four coils, four spark plugs, and wires to make the necessary connections. A pictorial arrangement of the ignition system is shown in Fig. 6.

Lubrication System. All moving parts in any mechanism must be lubricated in order to prolong their life. In a gasoline

Fig. 6. View of the Ignition System

motor the heat of the explosion must also be taken into consideration, which makes it a particularly difficult mechanism to lubricate. The lubrication system consists of a reservoir, means of lifting the oil to a higher level than the parts to be lubricated, and a pipe to carry the oil to the gear case in the front of the motor.

Cooling System. The explosions produce a great amount of heat and cause the cylinders to become very hot. Some step must then be taken to radiate this heat; if the cylinder becomes too hot, the piston will tend to expand to a larger size than the cylinder. The piston will then stick, and there will be total fail-

ure of motor operation. The cooling system consists of a radiator and a water jacket surrounding the cylinders. The water circulates through its jacket, lowering the temperature of the cylinders to a point where proper lubrication is possible. The water then passes through the radiator, where it is cooled. The circulating system of the Ford motor operates on the thermo siphon principle. As hot water, by its physical properties, is lighter than cold water, the hot water goes to the top of the cooling system from the motor. It is cooled in the radiator and travels down by gravitation; then it enters the cylinder water jackets at the bottom. This action continues until the motor stops and the water is cold. Fig. 7 shows the cooling system.

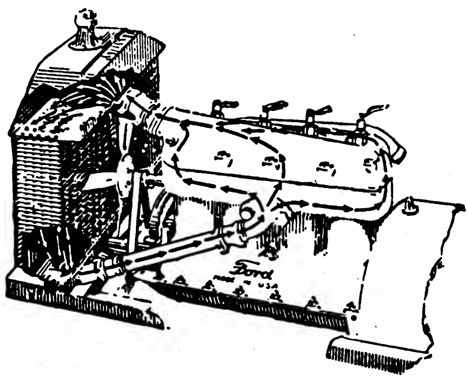


Fig. 7. Cooling System

Springs. There are two springs, of the semi-elliptic type; one mounted above the rear axle and fastened at each end to the axle housing by spring shackles and at the center to the frame by two spring clips; the other spring is mounted above the front axle and is fastened at each end to the axle by spring shackles and at the center to the frame cross member by two spring clips, as shown in Figs. 2 and 3.

Steering Mechanism. The steering mechanism is mounted on the left side of the car. (The left side of any car is always the driver's left when sitting in the driver's position.) The steering column is supported at the center by the dash and is bolted to the frame at its lower extremity. The front steering knuckles are fastened together by a connecting rod, or tie bar, and the steering column is connected to this bar by a drag link.

OPERATION OF PARTS

Motor. *Cycle.* The motor is a four-cylinder, four-cycle, L-head type. A four-cycle motor should really be spoken of as a four-stroke-cycle motor, as this type requires four complete strokes of the piston to produce an explosion; the word "stroke"

is generally omitted for brevity. In other words, one power stroke is produced from each cylinder every four strokes, or two revolutions of the crankshaft. As there are four cylinders in the Ford

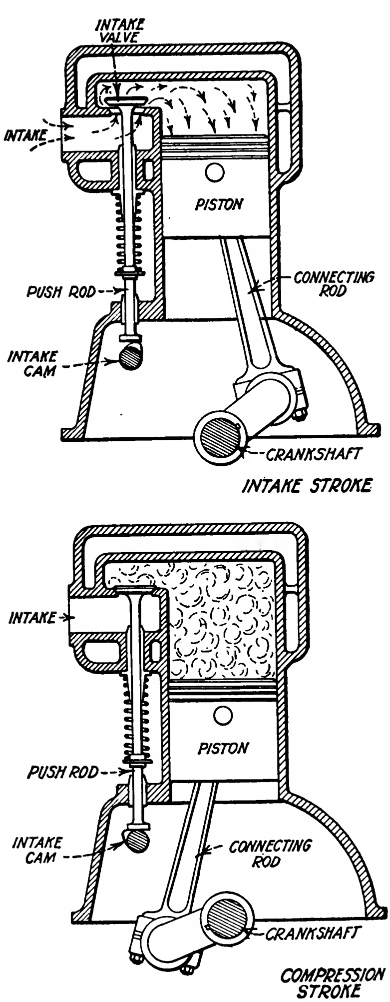


Fig. 8. Intake and Compression Strokes

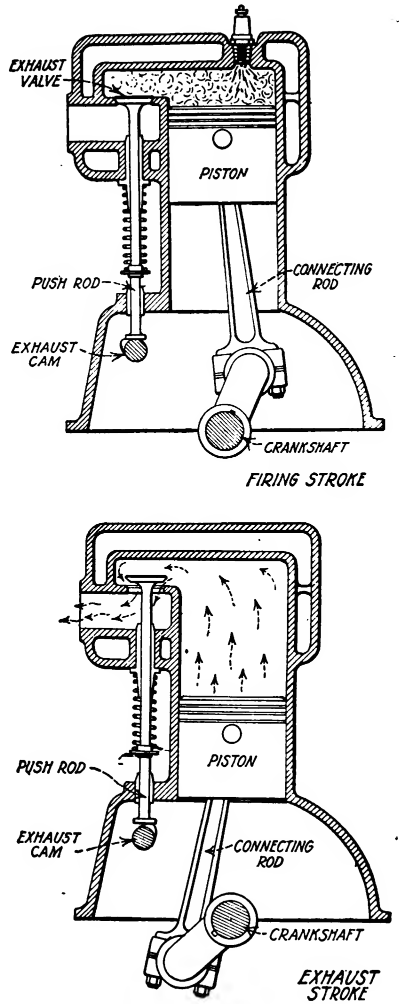


Fig. 9. Firing and Exhaust Strokes

motor, a power stroke is produced every half-revolution of the crankshaft. The operation of the intake and the compression strokes of the cycle are shown in Fig. 8 while the firing and the exhaust strokes are shown in Fig. 9.

Intake Stroke. As the piston starts down, the inlet valve opens and a charge of gas vapor is drawn into the cylinder.

Compression Stroke. The piston then moves upward, and as both valves are closed, the charge is compressed to a pressure of about 60 pounds per square inch.

Power Stroke. An electric spark then explodes this charge, increasing the pressure about four times, or to 240 pounds per square inch. This pressure drives the piston down with great force.

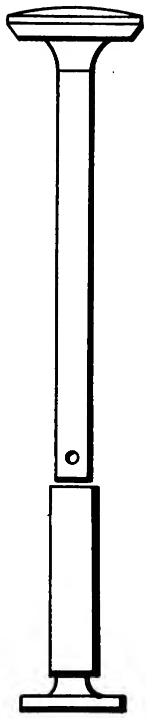


Fig. 10. Valve and Push Rod Assembly

Exhaust Stroke. The piston then moves upward—the exhaust valve opens before the piston reaches lower dead center—forcing the exhaust gases out of the cylinder, into the exhaust manifold, through the muffler, and into the atmosphere. This burnt gas must be expelled to make room for the fresh gas that is to be taken in at the next stroke. As both valves are on the same side of the motor, the cylinder and the combustion chamber have an inverted L shape. This is why it is called an L-head motor.

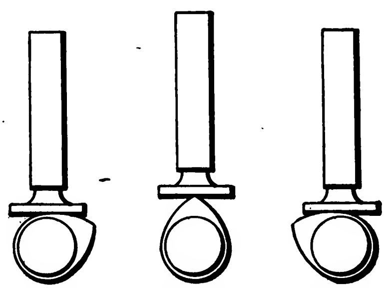


Fig. 11. Relation of Cam to Push Rod

Valve Mechanism. The valves are made of two pieces, a cast-iron head $1\frac{1}{2}$ inches in diameter and a steel stem $\frac{5}{16}$ inch in diameter and $5\frac{1}{8}$ inches long. The stem is welded to the head with electricity. The outer edge of the head forms the valve seat and is turned and ground to an angle of 45° to fit the valve seat in the cylinder. A small hole is drilled near the end of the valve stem to allow a pin to be inserted. This pin holds the valve

spring and seat in place. Operating directly under the valve stem is a push rod which is driven upward at regular intervals by a cam on the camshaft. These parts are shown in Figs. 10 and 11.

Camshaft. The camshaft is made of vanadium steel, hardened and ground on all cam and bearing surfaces to eliminate wear. The eight cams on this shaft, four intake and four exhaust, are forged integral with the shaft as this construction prevents any chance of loose cams. The camshaft and the valve assembly are shown in Fig. 12.

Fig. 12. Mechanism of Valves in Relative Position

Timing Gears. There are two gears in the timing-gear case located at the front of the motor. The drive gear is mounted on the crankshaft, and has twenty-one teeth in mesh with a driven gear which is mounted on the camshaft. As the driven, or camshaft, gear has forty-two teeth, it runs one-half as fast as the motor. This speed reduction is necessary as it requires two complete revolutions to produce an explosion; therefore, the intake valve and the exhaust valve must function once in two revolutions. These parts are shown in Fig. 12.

Piston. The piston is made of cast iron and is $3\frac{3}{4}$ inches in diameter. Its purpose is twofold. The piston rings are mounted

on the piston so that the compression can be securely held; it also transmits the explosive force to the crankshaft through the connecting rod. The piston must be a perfect fit in the cylinder, although a clearance must be allowed between the piston and the cylinder, this fit being secured by turning the piston and rolling the cylinder. The wristpin is mounted in the piston at each end, and the connecting rod is fastened to the center of this pin, the pin bearings being at each end of the pin. Bronze bushings are mounted in the piston and form a bearing surface for the pin. The pin is made of hardened steel, ground to the exact size, and is in the form of a tube for the purpose of reducing the reciprocating weight.

Connecting Rod. As several severe strains must be withstood by the connecting rod, therefore it is a vanadium-steel drop forging of the I section. Some manufacturers have used tubular connecting rods, but the I construction has been found to be the most satisfactory for connecting-rod use. The piston and connecting-rod assembly is shown in Fig. 13.

Fig. 13. Piston and Connecting Rod

Crankshaft. The crankshaft has three main bearings and is of the four-throw type. The front and center main bearings are shorter than the rear main bearing, as the rear bearing has the greatest amount of strain. Nos. 1 and 4 crankpins are in the same plane, the pistons of these cylinders traveling together; 2 and 3 are likewise in the same plane. The crankshaft is also a vanadium-steel drop forging, all bearings and crankpins being accurately

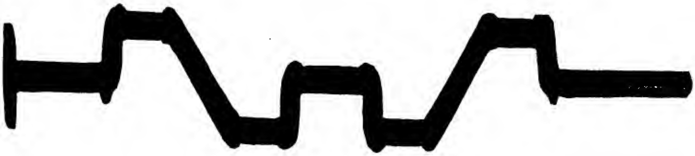


Fig. 14. Ford Crankshaft

turned and ground. The crankshaft is shown in Fig. 14; the end thrust of the crankshaft is taken up by the rear main bearing.

Flywheel. The flywheel is bolted to a flange at the rear of the crankshaft. A flywheel must be used to store up energy between the high and the low peaks of the power strokes. This energy is given off when there is but little energy being produced, this time being between the opening of the exhaust valve of one cylinder and the starting of the power stroke in the next cylinder to fire. It would be impossible to run the motor very slowly unless the flywheel was used.

Magnets. There are sixteen magnets mounted on the flywheel. These magnets are used in conjunction with sixteen coils to generate an electric current for ignition. In the early Ford models the lights were also supplied with current from this magneto. A complete description of this instrument will be found in the section on the "Electrical System," Part II.

Transmission. It is a generally known fact that transmissions are not used on steam cars or electric vehicles. The question then arises, why is a transmission—or change-speed gears—necessary in the gasoline automobile? To make this clear, it will be necessary to call to mind a few principles of the internalcombustion motor.

The Why of Transmission. The steam engine is an external-combustion motor; in other words, the fuel is burned in the firebox of the boiler, outside the cylinder. The steam pressure is generated in the boiler, and the steam is conveyed to the cylinder through a pipe. When the throttle is opened, the steam pressure forces the piston down. If there is a heavy load on the engine, preventing it from turning, the pressure will still be maintained until the boiler pressure is exhausted, the hot steam from the boiler supplying the heat that is absorbed by the cylinder. When the piston moves down a certain distance, the steam supply is shut off, this distance depending on the point of the valve cut-off. The steam contained in the cylinder then expands and forces the piston out the remainder of the stroke.

The action in the gasoline engine is very different from that in the steam engine as the gasoline engine is an internal-combustion motor; that is, the fuel, in the form of a gas, is taken into the cylinder as the piston travels down on its intake stroke. The inlet valve then closes and the gas is compressed as the piston

travels toward the combustion chamber. An electric spark then ignites this gas and raises the temperature to about four times that of the compression temperature. As the pressure is in direct proportion to the temperature, it is also increased about four times. Now, suppose that the motor is connected to a heavy load, as in the steam engine. The explosion is not strong enough to move the piston and the heat is quickly absorbed by the cylinder. This loss of heat lowers the pressure in the same pro-

Fig. 15. Section of the Ford Transmission

portion that it was originally raised, and since no outside heat can be added as in the steam engine, the pressure continues to decrease until it reaches zero.

All this heat which has been absorbed by the cylinders is wasted heat, or energy—all combustion motors are heat engines—and additional heat must be supplied in order to furnish constant pressure on the piston and produce a constant turning force, or turning torque, on the crankshaft. As this heat cannot be con-

tinuously supplied, it is necessary to use transmission reducing gears. This allows the motor to turn faster than the drive shaft, thus increasing the number of explosions per revolution of the drive shaft. This gives a greater turning torque to the motor and enables it to start the car under a heavy load and to climb steep hills when loaded. The transmission thus transforms the internal-combustion motor into a power plant which has an elasticity nearly approaching that of the steam engine.

Ford Transmission. The Ford has a planetary-type transmission which is entirely different from the transmission used on other pleasure cars. Fig. 15 shows the assembly of the Ford transmission, while Fig. 16 is a simple diagrammatic sketch showing the principle of its operation. The gear *C*, however, is eliminated in the Ford car and a small external gear is used instead. This does not alter the principle of operation. Let us suppose that the gear *B*, which is continually in mesh with the gears *A*, is mounted on the crankshaft of the motor. This gear will revolve in a clockwise direction as indicated by the arrow. The three gears *A* are mounted on the common spider *D*, and they are continually in mesh with the external gear *B* and the internal gear *C*. In order to obtain low speed, the gear *C* must be locked. The drive shaft is connected to the spider *D*, and this spider will revolve in a clockwise direction. As *B* is turning *A* in a clockwise direction, and as *C* is locked, the gears *A* will travel within *C* in a clockwise direction, or in other words, the spider *D* will revolve clockwise. When it becomes necessary to reverse the direction of the car, the gear *C* is released and connected to the drive shaft and *D* is locked. *B* will then cause the gears *A* to revolve on

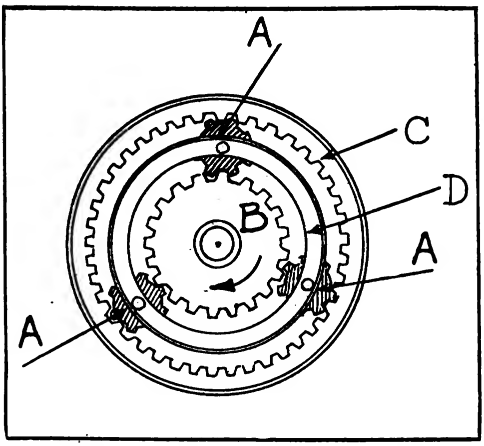


Fig. 16. Principle of the Ford Transmission

their spindles in an anti-clockwise direction, and as D is locked, the internal gear C will revolve in an anti-clockwise direction. When high speed is used, a separate disc clutch is operated which connects the motor crankshaft to the drive shaft. The entire arrangement then revolves as a unit, which has the effect of a flywheel.

Clutch. It is necessary to have some means of connecting and disconnecting the power of the motor from the rear wheels in order that the motor may be started and that the car may be put in motion without stalling the motor or causing the car to jerk.

Fig. 17. Construction of the Rear Axle

Fig. 35 shows the clutch parts. The clutch performing this function is of the disc type.

The clutch consists of a number of steel discs, half of them being fastened to the motor and the other half fastened to the drive shaft. The motor discs are set alternately between the drive-shaft discs. These discs are normally held together by a coil spring, thus causing the drive shaft and the motor to turn as a single unit. When the driver wishes to disconnect the power of the motor from the drive shaft, it is only necessary to release the tension of this spring to allow the discs to slip between each other. This is accomplished by the driver's pressing on the

clutch pedal with his left foot part way or by drawing up the control lever.

Rear-Axle Assembly. The drive shaft connects the clutch to the rear axle. As the shafts are mounted at right angles, it is necessary to transmit the power through a set of bevel gears. The standard ratio between these units is $3\frac{7}{11}$ to 1. There are two axle shafts connected at the center by the differential frame; the differential-gear arrangement, Fig. 17, shows the construction of the rear axle.

Differential. One of the most important mechanisms of any automobile is the differential, but as this unit causes very little trouble, few laymen are aware of its presence or realize its importance. It would be difficult to control the car without a differential when driving around corners since, when turning a corner, the outer wheel must turn faster than the inner one as the outer wheel is describing a larger circle.

Fig. 18. Principle of the Differential

The differential gear is used so that either wheel will be allowed to turn faster than the other and at the same time equalize the power transmitted to each wheel when driving straightaway. Fig. 18 shows the principle of the differential. Here it will be seen that the axle is divided into two distinct axle shafts. A bevel gear is carried at the inner end of each shaft, and these gears are keyed to the axles so that they revolve with them. Intermediate bevel gears are mounted on a spider and these

gears mesh continually with the axle gears. The ring gear is bolted to the housing, this housing turning as a unit with the intermediate gear spindles. The intermediate gears are free to turn on their spindles and do so when the resistance of one rear wheel is greater than that of the other. This resistance tends to hold the inner gear and prevent it from turning as rapidly as the other axle gear. The intermediate, or differential, gears then turn on their spindles, thus equalizing the power on the rear wheels. Now let us assume that all gears are in mesh, that power is being applied to the ring gear, and that the resistance is the same at both rear wheels. Then the entire assembly—comprising ring gear, differential, intermediate, or pinion, gears, and axle-shaft gears—revolves. If both wheels are turning forward at the same speed,

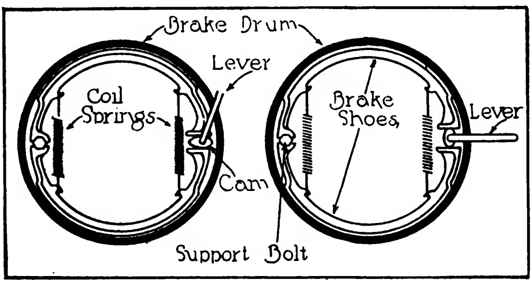


Fig. 19. Emergency Brake

the differential pinions remain stationary and merely act as a lock, forming a driving connection between the driving gears. This will cause both wheels to turn in the same direction as long as the load is uniformly distributed.

Brakes. The braking system forms a very important unit in the control of the car. If the motive power is disconnected by the clutch, the car will continue to move on account of its momentum, and it is therefore imperative that some means of stopping the car be provided.

There are two braking systems on the Ford car, one operated by a foot pedal, the other by the hand lever. The foot, or service, brake consists of a brake band operated on a brake drum in the transmission unit. When the foot pedal is depressed, this band is tightened, causing the speed of the transmission brake drum to

be checked. As this brake drum revolves at the same speed as the drive shaft, the speed of the car is materially lessened. This brake is the one to use when driving the car and is operated by the right-hand foot pedal.

The emergency brake is of the type shown in Fig. 19, where there is a brake for each wheel operating on the inside of the brake drum. The brakes used on the Ford models of a few years ago were of cast iron made in the form of two semicircular shoes. The brakes now used are made of cast iron in the form of a

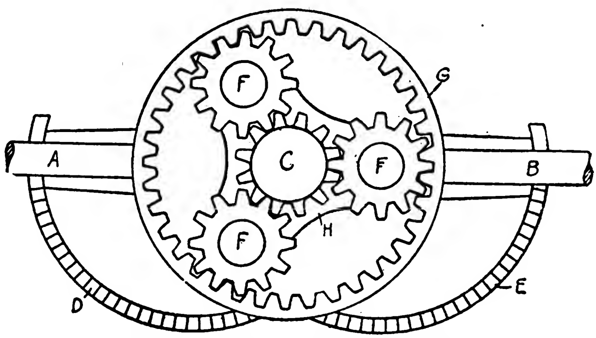
Fig. 20. Steering Column and Wheel

circular shoe. But the center portion of the shoe at the back is made very thin, so that there is considerable give without breaking. The shoe is split at the front to allow a flat cam to be placed between the ends of the brake shoe. Two coil springs are fastened between the brake shoes to hold them in the released position when the cam is flat. If, however, the cam is rocked, so that instead of lying flat it is moved to such an angle as to cause the brake shoe to spread, it will grip the internal surface of the brake drum and retard the movement of the wheels or

entirely stop the movement of the car. The braking effect depends on the distance the brake arm is moved by the driver. This brake is intended to be used only when the car is standing or it is necessary to lock the rear wheels when on a hill.

Steering Gear. Every car must have some suitable means of steering. The steering mechanism, however, must be so constructed as to give unfailing service without undue strain on the driver.

The steering, or wheel, post is a metal rod carried inside the steering column which is capable of being turned a certain number of degrees so that the steering arm connected to the drag link may be moved. This drag link is connected to the connecting



Gears in Steering Column: A, Spark Lever; B, Throttle Lever; C, Pinion on End of Steering Wheel Shaft; D, E, Quadrants; F, Spider Pinion Gears; G, Internal Gear.

Fig. 21. Steering Reduction Gears

rod which joins the steering knuckles. The turning of the steering wheel is thus transmitted to the front wheels in such a manner that the car may be satisfactorily steered. The limit of movement is determined by the distance the front wheels can be moved. Fig. 20 shows the construction of the steering column. The steering post is housed in a metal tube of sufficient size to carry the spark and the throttle control rods. These rods are worked by levers placed below the steering wheel and convenient to the driver's reach. The steering column is set at such an angle that the steering wheel is in a convenient position to the driver. The steering wheel consists of a metal spider having four arms terminating at the oval wooden rim; the intersection of these

arms at the center forms a boss. A hole is machined to allow the end of the steering post to enter and form a tight fit. A key prevents the wheel from turning on the steering post, and a nut screwed on the end of the steering post holds the wheel in place.

Ford Steering Gear. The Ford steering gear differs radically from the form used on the conventional car. The spider pinion gears, which permit a greater movement of the hand than of the steering arm, are located at the top of the steering post instead of at the bottom as in other cars. Instead of using the worm gear—the form most used in the average car—a planetary-gear arrangement is employed. These gears are in a compartment below the steering wheel and are packed with a lubricant to ensure perfect operation. The construction of this mechanism is shown in Fig. 21. This case contains four spur gears, one in the center, with three surrounding it. These three gears *F* are each mounted on individual studs, or spindles, the spindles being attached to a common triangular plate (or spider) *H* connected to the top of the steering post.

The casing *G* is provided with teeth on its inner periphery, and the three spur gears are in continual mesh with this internal gear. When the steering wheel is turned, the center spur gear *C*, connected to the steering wheel, turns the three gears, forcing them to travel around the inner periphery of the housing. This turns the triangular plate in the same direction but much slower. The driver is then enabled to handle the car very readily, even on unfavorable roads.

OVERHAULING THE CAR

Cleaning Car. One of the first steps in the actual work of overhauling the power plant is to clean the car very thoroughly. Any dirt or grit allowed to get into the bearings is likely to cause trouble by cutting the bearings when the car is again assembled. The gaskets must also be kept clean, although this is very hard to do if the adjacent surfaces are covered with dirt and grit. If particles of dirt get on any of the gaskets, it will be difficult to make a compression-tight joint. It is generally advisable to use new ones.

Identification of Parts. While the skilled mechanic is supposed to know where each and every part of the Ford car belongs, still the individual car owner or the apprentice mechanic is not usually so proficient, and a great deal of trouble will be avoided by marking the parts as they are removed from the car.

One method of marking is by small tags or by pieces of paper through which the bolts are forced. Particular care should be taken in marking those parts the use of which is not obvious. Another good method of identification is to number the parts with the same numbers that they carry in the Ford parts list. Such parts as the eight valves can be marked with a center punch, beginning at the front of the motor with one dot and proceeding toward the rear of the motor; the last valve will be marked with eight dots.

In using a center punch for marking the valves, the valves should be marked before removing to prevent bending the valve stem. Such parts as the gaskets for the radiator and the two screws holding the cylinder-outlet water-hose connection to the cylinder head can be tied on the radiator with a string. This method of tying the gaskets and other small parts to the larger parts to which they belong is a great time saver when the car is assembled. The use of cigar boxes, or boxes of miscellaneous sizes, in which to keep the parts of the different elements of the car is also helpful. For instance, all motor parts should be placed in one box, while the transmission cover bolts and other small parts belonging to the transmission should be placed in another box.

Removing Radiator. The radiator should be drained preparatory to removing it from the car. Removing the radiator makes it easier to get at the engine, commutator, and other parts. In order to drain the radiator, it is usually necessary to clean out the radiator drain cock after the cock has been opened, as mud and sediment usually accumulate in the bottom of the radiator. Fig. 7 shows the radiator and the hose connections.

The radiator is supported by a bracket at each side and by the water inlet manifold, with a truss rod between the dash and the radiator. This bracket is bolted to the side members of the chassis frame. The inlet manifold of the radiator is located in the center of the base of the radiator header tank, and the outlet

manifold is offset at an angle from the left side of the bottom tank, or base of the radiator. The inlet manifold is connected by a rubber hose and a flanged fitting bolted to the outlet of the water jacket at the forward end of the cylinder head. The outlet manifold is bolted to the intake of the water jacket at the left side of the cylinder block near the base of the water jacket. The radiator outlet manifold consists of a metal tube and a hose at each end; there is also a flanged fitting fastened to the cylinder block and connecting with this manifold. Two cap screws secure the flanges of the fitting at the outlet and at the inlet on the cylinder head.

PLUG

Fig. 22. Bottom of the Crankcase Showing Drain Plug

While the radiator is removed from the car, the radiator hose connections should be taken off and inspected. No doubt it will be advisable to put on three new hose connections at this time since this will tend to eliminate water leaks or clogged water hose at some future time. Sometimes new hose clamps are also needed. It is also a good plan to adjust the fan belt at this time, and if it is badly worn, it should be replaced with a new one. For regular use, either the leather or the fabric belt gives good results, and a belt with a coupling can also be carried in the car for emergencies.

Draining Oil. We are now ready to drain the old oil from the crankcase. After some use, the oil becomes black and dirty and is filled with metallic particles that have been worn from the bearings and other parts. Also, after the oil has been used for

some time it is much thinned out, since the kerosene condensed in the combustion chamber works down past the piston rings and destroys the lubricating qualities of the oil. Much wear and tear will be saved if the oil is changed about every thousand miles.

After removing the crankcase drain plug, located below the flywheel, and draining out the old oil, about 2 quarts of kerosene should be poured into the crankcase at the filler spout. The position of the drain plug is shown in Fig. 22. Then the motor should be turned by hand for several revolutions, splashing the kerosene around in the crankcase to clean out the old oil. If the front end of the car is jacked up about 6 inches, the kerosene will run back into the oil reservoir and drain out more completely. The drain plug should then be replaced. The old oil drained from the motor should not be used again in the crankcase; it is, however, satisfactory for spring lubrication and other minor places on the chassis.

OVERHAULING MOTOR

Preliminary Operations. The first part to be removed is the cylinder head; but before doing this, it is advisable to remove the four spark plugs to prevent them from being broken. Fig. 23 is a view of the motor showing the head detached.

The fifteen cylinder-head bolts should be removed with the socket end of the spark-plug wrench or a socket speed wrench, which can be purchased from any supply house. Less time is required when using the speed wrench.

Before removing the rear cylinder bolts, it is necessary to take off the small metal plate on the dash under the coil box.

If the valves are to be ground, it is advisable to remove the exhaust manifold, and the carburetor and intake manifold in one unit; this will permit easy access to the valves.

Before removing the carburetor, it is first necessary to disconnect the gasoline pipe. The gasoline supply should be shut off at the sediment bulb under the gasoline tank. It will also be necessary to lift the carburetor adjusting rod located on the dash.

In removing the exhaust manifold, it is easier to take out the exhaust pipe and manifold in a single unit by a straight pull forward. When removing the manifolds, be careful not to injure the

gaskets, as these gaskets ensure a gas-tight joint between the manifolds and the cylinder block.

Removing Valves. The first step when removing the valves is to remove the valve-chamber cover plates, after which the valve springs may be compressed by means of a suitable valve-lifting tool and the valve pins pulled out. These pins should be placed where they will not be lost. Two of the valves are always in the raised position, and it will be necessary to turn the crank until these valves go down, when the springs can be compressed and the valve pins removed.

Fig. 23. Motor Showing the Head Removed

Crankcase Repairs. We are now ready to remove the lower cover door of the crankcase. To do this, it is necessary to get under the car and remove the fourteen $\frac{5}{16}$-inch cap screws. A special speed wrench is made for spinning out these cap screws. This wrench, Fig. 24, is very short so that it can be used in the limited space. In removing the lower crankcase door, the gasket generally sticks and should be renewed. There is always some oil left in the connecting-rod dip pans on this cover, consequently one should not be directly under the pan when it is removed.

Adjusting Connecting Rods. We are now ready to tighten the connecting-rod bearings, which is best done one at a time.

Begin at the front connecting-rod bearing and examine the bearing cap to be sure that it is marked. There is a file mark on this cap on the side toward the camshaft, and if this bearing cap is not so marked, this should be done before the cap is removed. After removing the connecting-rod cap, file off a small amount of metal or remove one or more shims, if there are any. Then replace the cap and tighten the bolts, but do not replace the cotter pins at this time.

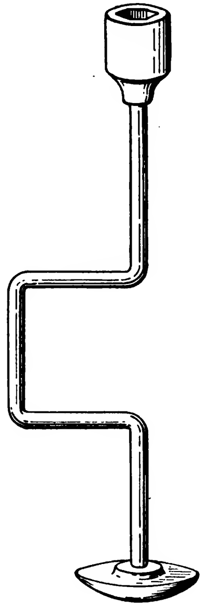


Fig. 24. Speed Wrench for Inspection Plate

Now try the tightness of the front connecting-rod cap by turning the starting crank. It should be possible to turn the crank, since the bearing should be a snug fit only.

After tightening the front connecting-rod cap, loosen the nuts on the bolts a couple of turns, then proceed in the same manner with the second connecting rod. If the cap is too tight when the bolts are securely tightened, place one or more shims between the connecting rod and the cap so that the engine will not be too hard to crank when all four bearings have been tightened.

The fourth connecting-rod bearing is generally about as hard to tighten as the other three put together for it is in a rather inaccessible location and requires the use of a special wrench, Fig. 25. A special universal socket speed-wrench can be secured from the Ford Motor Company.

After fitting the fourth connecting-rod bearing, the bolts on all four caps should be tightened.

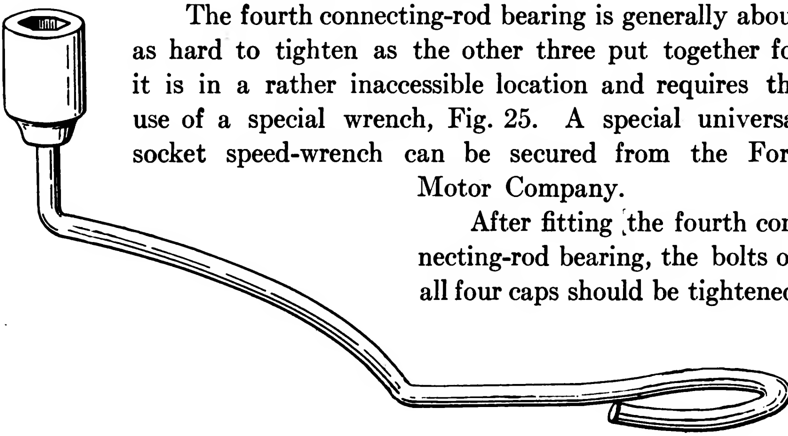


Fig. 25. Fourth Connecting-rod Wrench

Then the cotter pins should be put in and the ends of the cotter pins spread to keep them from dropping out.

Caution. Care should be taken not to get any broken ends of the cotter pins in the crankcase. Such bits of metal might be carried by the oil onto the magneto coils and cause a short circuit which might result in total failure of motor operation. A rag should be placed between the coil support and the crankcase.

Piston Slap. If there has been piston slap in the motor, new and oversize pistons should be installed at this time. It is sometimes advisable to rebore the cylinders when they are badly worn. This can be done in almost any good machine shop at small expense, or the small garage can do the job with a reboring tool made especially for that purpose. There are several of these reboring tools on the market, and they may be purchased at a supply house. If the original pistons which came with the car are still in the engine, then the new pistons should be 0.025 inch oversize. However, if the cylinder block has been rebored and is fitted with 0.03125-inch oversize pistons, then pistons .033-inch oversize should be installed.

Fig. 26. Removing the Carbon

Adjusting Main Bearings. Where there have been main-bearing knocks—they usually cause a deep heavy thud when the throttle is open and the motor is pulling hard—it will probably be necessary to remove the engine from the car and tighten the main bearings. This is best done when the motor is removed from the frame, thus making all of the bearings accessible.

While it is not difficult to tighten the middle main bearing through the crankcase-cover lower door without removing the motor from the frame, still the middle main bearing does not give trouble very often. It is the rear main bearing which is the most frequent offender.

The rear main bearing carries the load of the flywheel and magnets and the fore part of the transmission, in addition to the load due to the force from the connecting rods. So, in spite of the fact that this main bearing is made longer than the others, it has so much additional work to perform that it wears more rapidly and is generally the first of the three main bearings to give trouble. The front main bearing can be tightened without taking the motor out of the car if there happen to be some shims between the bearing cap and the cylinder block. It is only necessary to loosen the bolts, holding the front bearing cap in place, and pull out one or more shims and then tighten the bolts.

Fig. 27. Compressing the Valve Spring

Grinding Valves. In overhauling the motor, grinding the valves and removing the carbon are generally two of the most important details that must be undertaken. The carbon is easily scraped off the piston tops and the cylinder block by a putty knife or other flexible flat-bladed tool, Fig. 26. A steel scratch brush, such as is used to scrape sand from steel castings, is also useful for removing the carbon from the Ford cylinder head.

Before grinding the valves, it will be necessary to remove all the valve springs. This is best done by the use of some good valve lifter, several of which are on the market. The lifter holds the spring compressed, Fig. 27, while the pin is removed from the end of the valve stem.

The work of grinding the valves will be made much easier if the valves are refaced with a valve-refacing tool; if the valve seat is reamed with a valve tool, then a still better job can be had in much less time. These operations are shown in Figs. 28 and 29. After the carbon has been removed from the valves, a small amount of grinding compound should be placed on the edge of the valve where the seat is formed. A light push spring about 2 inches long and $\frac{3}{8}$ inch in diameter should then be placed on the valve stem, so that, when grinding, the valve will be lifted from its seat by this spring when the pressure is removed. This action is necessary to change the position of the cutting compound

Fig. 28. Refacing the Valves

and to prevent the valve seat from being grooved. The valve should be turned with a forked tool, Fig. 30; do not turn the valve in one direction only as this will groove the seat. The spring should then be allowed to lift the valve, and when it is lifted, it should be turned so that the position of the grinding compound will be changed. This compound is sold in a box with two compartments, one containing the coarse and one the fine compound. The fine compound is generally satisfactory for the intake valves.

After grinding the valves, great care should be taken to clean out all the grinding compound. Do not allow the compound to

get on the pistons or the cylinder walls as it will cause a great deal of wear if left on these parts.

Inlet Valves. In grinding the valves, it will be noticed that the inlet valves are not usually pitted and scored as much as the exhaust valves. The reason is that the exhaust valves are subjected to the hot flame of the exhaust gases, while the inlet valves are cooled by the fresh incoming gases from the carburetor. For this reason the exhaust valves become much hotter

Fig. 29. Refacing the Valve Seats

than the intake valves. This heat usually burns the carbon from the exhaust valves, while the tops of the intake valves are covered with carbon. As the inlet valves are generally in fair condition, it is not necessary to reface them to the same extent as the exhaust valves.

If the motor has been in use for several years, it sometimes happens that there is sufficient wear around the stems of the inlet valves to cause air leaks at these points, Fig. 31. This air

leak will sometimes allow enough air to pass into the intake manifold to cause the motor to miss at low throttle openings; it will also make starting difficult. Replacing the valves will reduce this leakage to a certain extent, but sometimes the valve guides are worn and replacing the valves is not sufficient. Then it will be necessary to install valves having $\frac{1}{64}$-inch oversize stems. When valves having oversize stems are used, ream out the valve-stem guides with a $\frac{1}{64}$-inch oversize valve-guide reamer.

Adjusting Valves. After replacing the valves, it is necessary to adjust the valve-tappet clearance, which should be between $\frac{1}{64}$

Fig. 30. Grinding the Valves

and $\frac{1}{32}$ inch. For passenger-car use, where one desires to obtain a quiet-running motor, less clearance than $\frac{1}{64}$ inch can sometimes be given. This tends to eliminate valve-tappet noises and clicks, but it will also cut down the power of the motor to some extent. Not less than 0.008 inch or 0.010 inch clearance for the inlet valves and not less than 0.015 inch clearance for the exhaust valves should be allowed. No adjustment has been provided by the Ford Motor Company, so if it is desired to make this adjustment a set of valve-adjusting discs should be purchased. If the stems are too long, they may be shortened by filing.

It sometimes happens, after the reground valves have been run in the engine for a short time, that the valves seat themselves more deeply into the cylinder block, thus reducing the clearance between the ends of the valve stems and the tappets. For this reason, it is better not to replace the covers of the valve chambers but to measure the valve-tappet clearance and adjust the valves

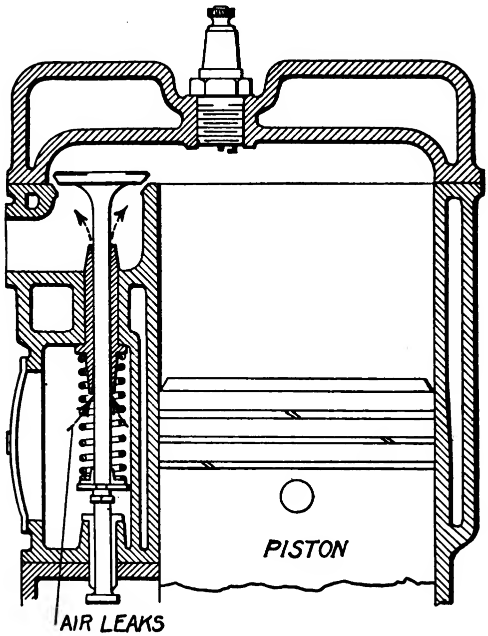


Fig. 31. **Air Leaks around the Valve Stems**

again after the engine has been running for fifteen or twenty minutes.

The clearance should be checked with a thickness, or feeler, gage, consisting of a number of thin strips of steel. If this tool is not at hand, an approximate valve-tappet clearance adjustment can be secured by using a postal card as a thickness gage. Such a card is about 0.010 inch in thickness.

Assembling Motor. After cleaning off the carbon and grinding the valves, the cylinder head should be replaced. But before doing this, the cylinder-head gasket should be carefully cleaned. It is not necessary to buy a new gasket if the old one has been removed with reasonable care and is not torn or broken.

When replacing the cylinder head, turn the starting crank so that the first and fourth pistons are in the extreme raised position—on upper dead center—and are projecting above the cylinder block. The pistons will hold the gasket and keep it from slipping when in this position. Smearing both sides of the cylinder head with heavy grease not only helps to keep the gasket in position, but it will also assist in making a compression-tight joint, as the grease allows the gasket to work to the correct position and fit smoothly between the cylinder head and the cylinder block.

It is also a good plan before replacing the cylinder head to clean the carbon and dirt out of the cylinder bolt holes, using a twist drill about $\frac{3}{8}$ inch in diameter. If this dirt is not cleaned out of the bottom of these holes, it will be impossible to tighten the bolts enough to make a compression-tight joint between the cylinder head and the motor block. The bolts are also likely to

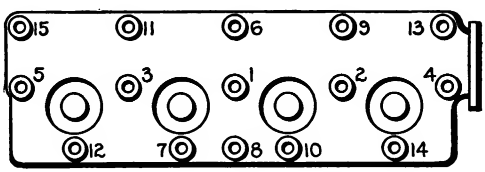


Fig. 32. Tightening Cylinder Head Bolts

be twisted off when they are being tightened. After replacing the cylinder-head bolts, spin them down with a speed wrench and then tighten them with the cylinder-head and spark-plug wrench. It is not necessary to tighten these bolts with excessive force, as they may be broken if this is done. There is a certain knack in tightening these bolts. The center bolts should first be tightened and then the bolts on each side, working toward the ends of the cylinder heads, until all the bolts have been tightened. They should then be gone over for a final tightening. The bolts should be tightened in the order shown in Fig. 32; if they are first tightened at one side or at one end of the cylinder head, a compression-tight joint is hard to make and leaks may occur.

Inspecting Spark Plugs. We are now ready to inspect the spark plugs, which should be taken apart and cleaned before being replaced in the cylinder head. Emery cloth should not be used to clean the porcelains as it will remove the glaze and allow

oil to soak into the porcelain; then the spark plug will short-circuit very easily.

After assembling the porcelain and the body of the plug, care should be taken not to make the nut too tight, as the heat of the engine may crack the porcelain.

Adjust the gap between the spark-plug points to $\frac{1}{32}$ inch and bend the grounded point of the electrode upward; then, if oil collects on the points, it will not bridge the gap but will run off to the side where it can do no harm. This adjustment is shown in Fig. 33.

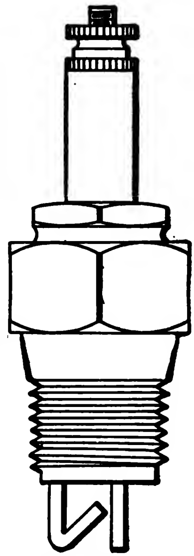


Fig. 33. Spark Plug Adjustment

Wiring. The timer wires should be replaced if they are oil soaked and badly worn or if the insulation is broken near the commutator. When examining the timer wires, stray ends should be carefully looked for, as these fine ends may touch the motor when the spark lever is moved and cause the motor to miss. The commutator wires require much more attention than the high tension cables that lead to the spark plugs. The color of the wires indicates the terminal to which they should be attached.

Timer. The timer should be taken apart and well cleaned, and if the raceway on the inside of the timer shell is worn or rough, this shell should be replaced. A worn timer shell will cause the roller to bounce and this, in turn, may cause misfiring of the engine at speeds of 25 m.p.h. or over. The timer roller assembly is another small part which sometimes causes much trouble. If the timer roller is worn, or the timer spring weak or broken, it is advisable to replace the entire roller-brush assembly.

Coil Adjustments. Another part of the ignition system upon which much of the smooth running of the motor depends is the adjustment of the vibrator points of the spark coils. These coil points should be ground smooth and true, so that they make good contact. After the coil points have been worn down about half-way, it is usually necessary to replace them with new ones in order to get an effective coil-point adjustment.

If possible, the coils should be taken to the nearest Ford agency where there is a coil-testing machine and adjusted until each unit consumes from 1.2 to 1.4 amperes as indicated by the ammeter of the coil-testing machine. The coil points should separate about $\frac{1}{32}$ inch when the vibrator is pressed down against the core of the coil unit. Fig. 34 shows the adjustment of this unit.

Preparing Motor to Run. After having made sure that the crankcase drain plug has been tightened and the crankcase lower door replaced, a gallon of clean oil should be poured into the crankcase.

We are now ready to replace the radiator and to fill it with water. After filling the radiator, the joints around the radiator hose connections and between the cylinder head and the cylinder block should be examined to see whether there are any leaks.

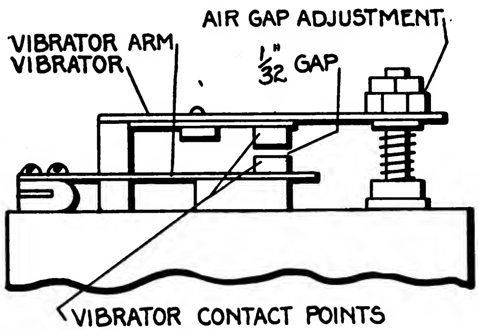


Fig. 34. Adjustment of the Spark Coils

The engine can now be run as slowly as possible for five or ten minutes until the oil is worked into all the moving parts and the parts which have been replaced have had a chance to adjust themselves to each other. If new piston rings have been installed or if the connecting-rod bearings have been tightened, the engine should be run for an hour or so at a slow speed but with plenty of oil to give these parts a chance to work into good running condition.

OVERHAULING TRANSMISSION

Noisy Transmission. After a car has been run for several thousand miles, especially in hilly country, the transmission becomes very noisy and will grind when either the low-speed or the reverse-speed brake bands are operated. As there is no power transmitted through the gears when the car is running in high

speed, little trouble will be had with the gears when the car is being driven in high. The discs in the clutch assembly may be roughened or worn enough so that they cannot be adjusted any further by means of the clutch-adjusting screws. When the power plant is out of the chassis, it is advisable to examine the transmission gearing if unusual noises have been present. The gears should not wear very much, although the bushings in these gears are subjected to considerable wear.

Tearing Down Transmission. *Clutch-Disc Assembly.* In taking the transmission apart, it is first necessary to drive out the clutch spring and the thrust ring support pin, which makes it possible to remove the clutch shift collar, *Group 5,* Fig. 35. The driving plate can be removed after the screws bolted to the brake drum are taken out. The clutch-disc assembly is then exposed as shown in *Group 4.* The clutch discs are carried by the disc drum as shown in *Group 1.* A set screw holds this member securely to the rear end of the crankshaft. After this set screw is loosened, the disc drum may be removed and the assembly will then appear as in *Group 3.*

Drum Assembly. The remaining part of the assembly, consisting of reverse drum, low-speed drum, brake drum, and triple gears, may be easily withdrawn from the flywheel and the crankshaft extension known as the transmission shaft. The assembly is then as shown in *Group 2.* In order to take down the remainder of the assembly, the driven gear must be removed from the brake-shaft extension, allowing the three drums to be pulled apart. The bushings in the triple-gear assembly must be examined after the transmission has been taken apart. It is also necessary to examine the pins attached to the flywheel that support the triple gears. If either the bushings or the pins are worn, there will be considerable play and the transmission will be very noisy when operating in low or reverse speed. If the bushings are worn, they should be removed and new ones installed, special care being taken to see that the new bushings are reamed concentric so that the gears will revolve true. The pins mounted on the flywheel should also be replaced if worn. The bushings in the reverse drum and gear and in the interior of the low-speed drum and gear should be carefully examined to make sure that the low-

speed drum is a good fit on the sleeve of the brake drum; the reverse drum should also fit properly on the extension of the low-speed drum. If these bushings are worn so that it is considered advisable to install new ones, they should be removed and new ones forced in place by means of an arbor press or a vise.

Before reassembling the brake-drum unit, the bushings should be fitted to turn freely on the members by which they are supported. The surfaces of the brake, the low-speed, and the reverse drums should not be cut or scored. This scoring often happens when transmission bands are riveted in place with iron or steel rivets. Soft copper or brass rivets should always be used for this purpose, and the rivets should be properly countersunk.

Clutch Discs. The clutch discs should be removed, thoroughly cleaned, and inspected to see if there are any rough surfaces. If there are ridges on the plates which come together—a result of the operator continually slipping the clutch—the ridges should be removed with a file; if this thins down the plates too much, new plates should be used. It is advisable to install new plates if they are rough, as this also indicates that the plates are soft.

Assembly of Transmission. The first parts to be assembled are the reverse drum and gear, driven gear, low-speed drum and gear, and brake drum, as shown in *Group 1*, Fig. 35. These parts form *Group 2*. The brake drum should be placed on a bench with the hub extending upward and the low-speed drum should be placed over this hub with the gears on top. The reverse drum is then placed over the low-speed drum with its gear member up. The two Woodruff keys that connect the driven gear to the brake-drum hub are then put in place as shown in *Group 1*. The driven gear is then placed with the teeth downward so that it will be next to the low-speed gear; the triple gears are then meshed with the driven gear, making sure that the punch marks on the teeth correspond with one another. The reverse gear—the smallest one of the three comprising the assembly—should be on the bottom, or down. When the triple gears have been properly meshed, they should be securely tightened in place with a spring or wire; the assembly will then be as in *Group 2*.

Group 2 should then be assembled on the flywheel. The flywheel is placed on the bench with its face downward, the trans-

mission shaft projecting upward. The *Group 2* assembly is turned over so that the triple-gear assembly will face the flywheel. Then the group is so placed on the transmission shaft that the triple-gear pins will pass through the bushings in the triple gears. The assembly will then have the appearance of *Group 3*. The assembly should slip readily in place. If it is necessary to use force, the pins may be bent, or the gears not properly meshed, or the bushings not reamed.

The clutch-drum key should then be fitted in the transmission and the clutch-disc carrier drum placed on the shaft, locking it in place with a set screw provided for that purpose. A heavier disc than the disc plates is put on the clutch drum first; then a small clutch disc, and then a large one. This heavy disc, or distance plate, is not used on the later Ford models. The small and large discs are then added alternately until all the discs are in position. A large disc having keyways on its outer periphery should be on top when the set is assembled. If a small disc having keyways in the inner periphery is left on top, it is likely to drop over the clutch drum.

When changing from high to low speed, it is impossible for the high-speed clutch to be engaged. With the clutch-disc drum and the clutch discs in place, the transmission would have the appearance of *Group 4*. It is then necessary to put the clutch-disc ring over the clutch drum and the clutch push-ring over the clutch drum and on top of the disc ring, with the three pins projecting upward as in *Group 5*. The remaining parts are then assembled in the order shown in *Group 5*. The driving plate should be bolted in position on the brake drum so that the adjusting screws of the clutch fingers will bear against the clutch push-ring pins. It is then advisable to test the transmission by removing the drums and plates with the hand. If properly assembled, the flywheel will revolve freely while any of the drums are being held, or vice versa.

Assembling Clutch. The clutch parts may be assembled on the driving-plate hub by slipping the clutch shifter on the hub so that the small end rests on the ends of the clutch fingers. The clutch spring should then be replaced with the clutch support inside so that the flange of that member will rest on the upper coil of the

spring. Next place the clutch spring and the thrust ring with the notch end down on the driving-plate hub and press the spring into place, inserting the pin in the driving-plate hub through the hole on the side of the spring support. One of the best methods of compressing the spring sufficiently to insert this pin is to loosen the clutch-finger tension by backing out the adjusting screw. When these screws are again tightened, the springs should be compressed to a length of 2 or $2\frac{1}{16}$ inches to ensure against clutch slippage. Care should be taken that these screws are uniformly adjusted so that the even compression of the clutch spring is obtained.

Another method is to assemble the spring on the drive plate before installing it on the transmission. A vise or arbor press may then be used to compress the spring. To relieve the pressure on the fingers, a cap screw should be placed between the plate and the shifter.

OVERHAULING FRONT-AXLE SYSTEM

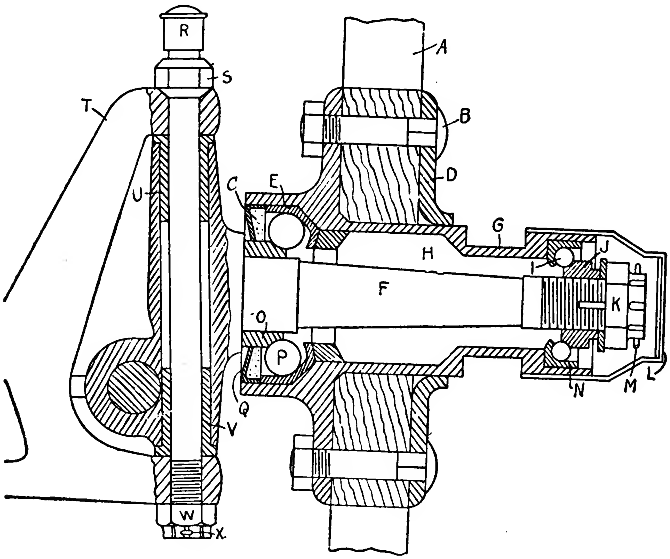
Inspection of Parts. In overhauling the front-axle system, one should first take off the two front wheels and clean the grease from the ball bearings and from the hubs of the wheels. After removing the ball bearings, the steel balls should be carefully inspected for any flaws, pits, or cracks; even a tiny defect is sufficient reason for throwing them away. The surface of a ball is the important part, and a small crack or flaw will cause the cutting of the cone and ruin the entire ball bearing. A cross-section of the front spindle is shown in Fig. 36.

The cones and cups of the front-wheel bearings should be carefully examined for signs of wear. As a rule, it is advisable to replace the old cups and cones with new ones, as worn cones will make it impossible to obtain a satisfactory adjustment of the front-wheel bearings. When the hardened surface of the cone is worn away, the cones will then wear away rapidly.

Turning the cones upside down is sometimes suggested, thus bringing the wear on the opposite side of the bearing. This practice, however, is not to be recommended as it is almost impossible to obtain a satisfactory adjustment, one which will be easy running and not wobble, when the cones are worn to this

condition. These cups and cones are shown at *J* and *N* and also at *O* and *E* in Fig. 36.

While the front wheels are off the spindles is a good time to examine and replace the spindle-body bushings and the spindle-arm bushing. In order to remove the spindle-body bushings, it is usually necessary to use one of the special drifts, or punches, which are made for this purpose by some of the accessory manufacturers. If one of these drifts cannot be obtained, the bushings



Sectional View of Front Wheel Spindle. A, Spoke; B, Bolt; C, Oil Retaining Wick; D, Hub Flange; E, Outer Ball Race; F, Spindle; G, Hub; H, Grease Space; J, O, Inner Races or Cones; K, Lock Nut; L, Hub Cap; M, Cotter; N, Outer Race; P, Large Ball Bearing; Q, Ball Retaining Ring; R, Spindle Oiler; S, Spindle Bolt; T, Front Axle; U, Spindle Bushing; W, Spindle Bolt Nut; X, Cotter Pin.

Fig. 36. Cross-Section of Front Wheel Spindle

can be driven out by tapping a $\frac{9}{16}$-inch eighteen-thread tap into a spindle-body bushing and then using an old spindle-body bolt to drive out both the tap and the bushing.

As a rule, it is advisable to replace the spindle-body bolts when the bushings are replaced, especially if the bolts show any sign of wear. After the new bushings have been driven into the spindle body, it is necessary to ream them out, for which purpose special reamers are made and can be purchased at accessory houses.

While working at the front-axle system, the nuts on the end of the front radius rod should be securely tightened and then cotter pinned. If the slots for the cotter pin in the nut do not come into alignment with the holes at the ends of the front radius rod, the nut should be removed and a small amount of metal ground or filed from the face of the nut, after which the nut should be again tightened up. With a little practice, the nut can be adjusted to turn to the correct position by filing off metal in this manner.

The late Fords are being equipped with radius rods fastened to a perch under the axle.

If the nuts on the end of the front radius rods are not kept tight, the vibration on the end of these rods will cause fatigue of the metal and eventual breakage, thus possibly causing an accident. Also, if the nuts on the front ends of the radius rods are not kept tight, the front axle will not be held at the proper slant to give easy and steady steering.

Adjusting Front Axle. *Correct Slant.* The adjustment of the slant of the Ford front axle is of great importance in making the car easy to steer and in saving wear on the tires. If a line is drawn through the axis of the front-spindle bolt, Fig. 37, this line should strike the ground about $1\frac{1}{2}$ inches in front of a vertical line dropped through the center of the axle. By inclining the front axle in this manner, the front wheels are given a trailer, or caster, action, which tends to make them come to a straight-ahead position, just as the front wheel of a bicycle does when the bicycle is held upright and pushed ahead. This steering action of the Ford front-axle system relieves the driver of much strain and fatigue.

Another method of adjusting a front axle to the proper inclination is by tying a weight on the end of a string and using it as a plumb bob. Allow the string to touch the lower side of the front-axle yoke in front of the car, Fig. 38. Under this condition, the string should be about $\frac{3}{8}$ inch, or about the thickness of a lead pencil, from the top arm of the front axle.

Still another way to test this front-axle alignment is by the test method. In using this method, it is necessary to drive the car and see whether the front wheels swing quickly into the

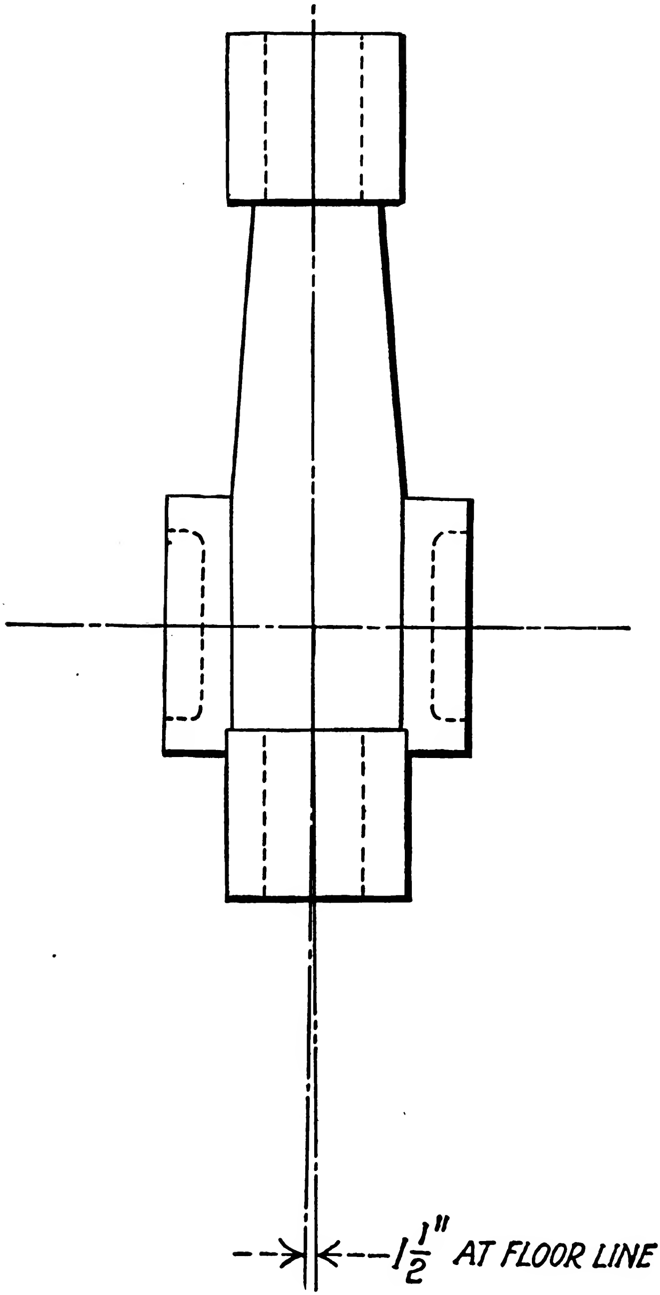


Fig. 37. Checking Adjustment of Front Axle

straight-ahead position after being turned to one side or the other. Of course, this test is made on a smooth level road.

If the front axle is given too much slant, there will be too much tendency for the wheels to come to a straight-ahead position, and the driver will have to exert undue strain and force when turning a corner. For straightaway racing, at high speed on board tracks, it is the custom of some Ford racing drivers to give the front-spindle bolts as much slant as two or three inches, as racing on large tracks does not involve any short or sudden turns.

In order to get the correct slant on the front axle, a large monkey wrench—say a 30-inch size—or a special front-axle tool made for this purpose, Fig. 39, can be gripped at one end of the front axle and used to bend one side of the radius rod, or "wishbone." After bending one side in this manner, the monkey wrench or special tool is shifted to the other side of the front axle, near the other wheel, and then the other side of the axle is given the same slant. The Ford Motor Com-

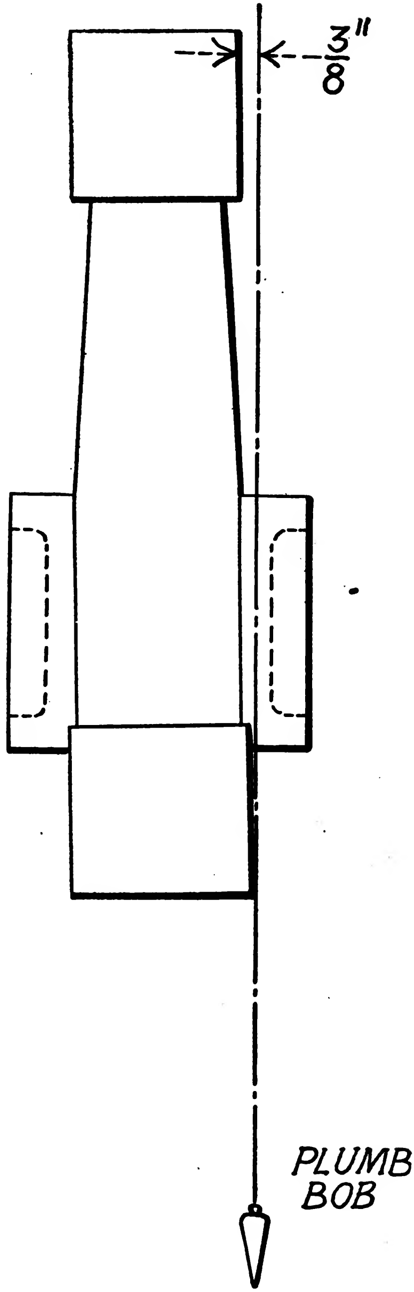


Fig. 38. Checking Front Axle with Plumb Bob

pany recommends that when the radius rods are badly bent they should be replaced with new ones.

Ball Socket. It is usually found that the front-radius-rod ball socket wears loose in time, even though springs are provided under the nuts of the front-radius-rod studs to take up the wear. After a year or so of use, it will be found that these studs are badly worn; as they only cost a few cents each, it is advisable to replace them in order to get smooth steady action in the front radius ball socket.

While the studs are out is a good time to file a little metal from the face of the ball socket on the base of the crankcase. It might be thought that removing metal from the face of the ball-socket cap would be sufficient to eliminate such wear as might be present, still the socket in the crankcase also wears and it is best to file it too.

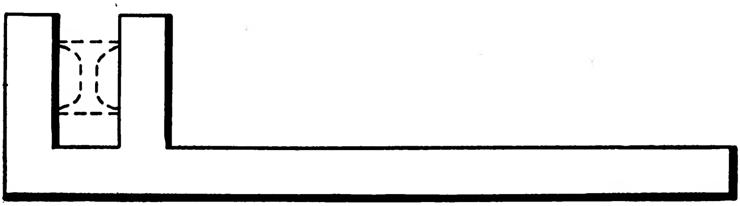


Fig. 39. Wishbone Straightening Tool

As the bolt holes in the front-radius-rod ball caps are usually badly worn, it is suggested that the ball caps be replaced rather than an attempt made to file the metal off their faces. Of course, if the car has been in use for only a short time, filing some metal from the face of the ball cap will make this joint tight enough for all practical purposes. Much of the rattle is often due to a loose joint in the front-radius-rod ball socket and it is worth while to take particular care in adjusting this socket.

Adjusting Front-Wheel Bearings. After examining the cups of the bearings in the front wheels and replacing such cups as may be worn, we are now ready to replace the wheels on the spindles. If any one of these bearings is not a drive fit into the front hub, several shims may be placed between the bearing cup and the sides of the hub. This is to prevent the bearing cup from turning inside the hub, as all the turning should be done on the

ball bearings. The shims used should not be thick or heavy, for if the cup is too tight a drive fit into the hub, the bearing cup may be slightly distorted—out of round—when driven into the hub. It is better to use several thin shims equally spaced around the hub and thus center the ball cup in the middle of the hub than to use a single thick shim at one side. This practice, however, is not recommended.

The adjustment of the front-wheel bearings should be made so that the weight of the valve stem is sufficient to start the wheel in motion and to make the wheel roll to and fro. Yet the bearings should be carefully adjusted so that there is no percepti-

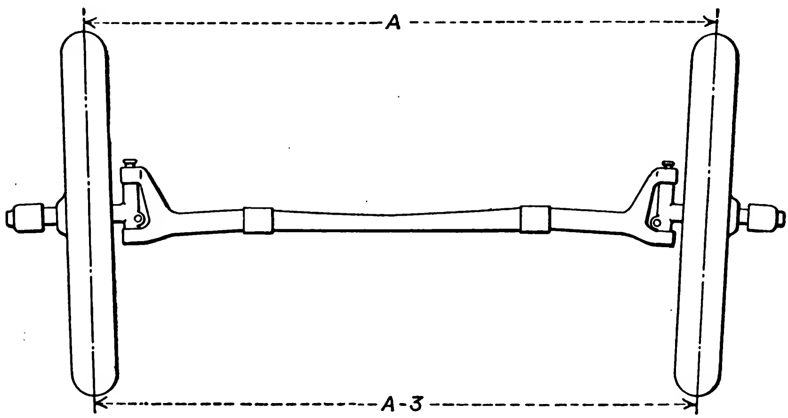


Fig. 40. Adjustment of Front Wheels

ble shake or play when the spokes are gripped and the wheel is shaken.

Before leaving the front wheels they should be checked up for alignment. These wheels should be 3 inches closer together at the bottom than at the top, Fig. 40. The purpose is to bring the point of contact between the tire and the ground more nearly under the point of rotation of the spindle-body bolt. This makes it easier to steer the car and, by having the point of contact between the wheel and the ground come more nearly in the same straight line as the spindle-body bolt, there is less chance of rocks or stones swinging the wheels to one side. This makes it easier to drive the car on uneven rocky roads.

We all know that when a rolling hoop is tilted to one side or

the other, it tends to turn a corner or roll to one side in the direction in which it is slanted. The same action takes place in the case of the Ford front wheels, and as the front wheels are slanted outward at the top, they tend to run outward. This tendency would cause undue friction and tire wear if it were not corrected by giving the front wheels a little "gather" to make them $\frac{1}{4}$ inch closer together in front at a point about 16 inches above the ground.

EQUIPPING FORD FRONT HUBS WITH TIMKEN BEARINGS

Sets of Bearings. Ford closed models and 1-ton trucks have for some time past been fitted with special Timken roller bearings on the front wheels. The same bearings can also be installed in other models to replace the old cup-and-cone bearings, as these sets are interchangeable. The Ford Motor Company supplies the bearings in separate packages or cartons; a complete set of bearings for one wheel is in each package. As the Ford spindles have right- and left-hand threads, it is, of course, necessary to supply adjusting cones for the outside bearings with corresponding threads. The packages containing the complete sets of bearings are plainly marked "right wheel" or "left wheel," according to the set each package contains.

Removing Old Bearings. When installing Timken bearings in the Ford front wheels in place of the old bearings, the first step is to remove the old bearings from the wheel hubs and clean out the hub thoroughly so that no grit or metal chips will be left to damage the new bearings The shoulders of the recesses from which the ball cups were removed should be inspected carefully for high spots, which might cause the cups of the Timken bearings to set high on one side.

The stationary cone is also removed from the inner end of the spindle as it is to be replaced with a special cone. Be careful not to leave rough or high spots on the part of the spindle on which the cone seats, as the Timken inner cone is not pressed onto the spindle, but is a floating slip fit. It has a clearance on the spindle of 0.001 inch.

Installing Cups. Both the inner and the outer cups of the Timken bearings, corresponding to the inner and the outer ball

races, or cups, of the old bearings, are press fits in the hub of the wheel. The best way to install them is to draw them both into place at once with a special puller, similar to that shown in Fig. 41. The large or square end of this device is held in a vise or with a wrench while the special handle nut on the other end is turned, forcing the races in position.

Tools of this type can be purchased from the Ford Motor Company, or they can be made in the repair shop from cold rolled steel and a simple forging.

Fig. 41. Tool for Installing Bearing Races

If no special puller is available, the cups can be driven into the hubs, but care must be exercised to drive them evenly all the way around their circumference. A special driver or arbor, Fig. 42, is very useful for this purpose. One end of this driver is used on the large, or inner, cup and the other end ou the small, or outer, one. The inside cone faces of the cups must

not be struck or marred in any way when pressing the cups into the hub.

Securing Press Fits. As with the cup-and-cone bearings, the Timken cups must be press fits in the hub. It is advisable to try both cups by hand to make sure they will not fit too loosely before attempting to press either one into place. Sometimes a hub will be damaged and the recess for one of the cups expanded somewhat as a result of some of the balls being broken in the old bearing.

If either bearing cup of the Timken set is a loose fit in the hub, it is safest to install a new hub, as there is no satisfactory method of making a bearing cup a tight fit in a hub too large for it. Some repair men attempt to make a cup a tight fit by putting strips of paper or emery cloth between the cup and

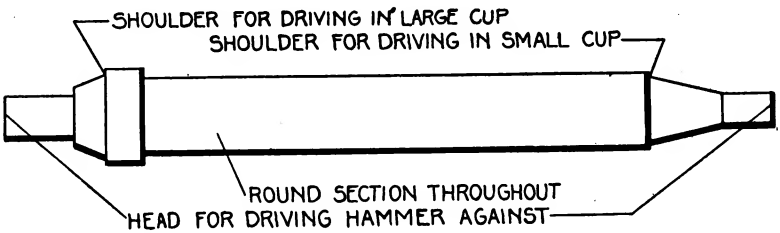


Fig. 42. Special Bearing Replacer

the hub recess; with either material there is a grave danger of getting the cup out of true. If paper is used, it soon becomes soaked with grease and pounds or works out of place, leaving the cup loose. On the other hand, emery cloth cannot be used at all unless the cup is entirely too loose and sloppy a fit in the hub recess. To put it another way, if the hub is so large that it is possible to use emery paper to make the cup a tight fit, it is not safe to use the hub. The emery is also liable to get into the bearing and hasten the wear.

The depth of the outer race recess in the latest front hubs is $\frac{3}{4}$ inch, but in older hubs it is $\frac{19}{32}$ inch. Some variation may occur, therefore, in the depth to which the outer, or smaller, cups of the Timken bearing sets can be pressed in the front hubs of various cars.

The principal thing to look out for in connection with the outer cups is to see that they are pressed into place evenly and are not high at any spot. It is unimportant if some cups project slightly beyond the end of the hub, are flush with it, or set in slightly, provided they have been pressed in all of the way and run true.

To test the fit of the inner, or large, cup, be sure the distance from the outer face of the cup to the edge of the hub at several different points around the cup is even, Fig. 43. A fine scale should be used, preferably one divided into 64ths, as a very slight difference in the depth of the cup at any one point would cause it to run out of true.

In removing the races used for the ball bearings, the hub surface is sometimes burred. This burr may seem very small and of no consequence, but at the same time it is in a position to cause excessive wear. Care should therefore be taken to prevent these burrs when the old races are being removed.

If burrs are present they may be removed with a fine chisel and emery cloth. A little sand or grit will cause the same trouble and to avoid the presence of grit, the races and hubs should be thoroughly cleaned with gasoline or kerosene and a stiff brush.

Fig. 43. Checking Evenness of Bearing Cup

Cones and Rollers. A plentiful supply of a good cup grease should be packed into the hub as well as into the inner and the outer cones and roller sets, the spaces around and between the individual rollers also being filled. The larger inner cone with its rollers is then placed in the inner cup, and the dust ring and the felt washer are driven into the large end of the hub so that the dust cap is flush with the end of the hub.

It will be noticed that the rollers of the Timken bearings are assembled with the cones instead of with the cups, or races, as

are the cup-and-cone bearings. For this reason, the large inner cone must be a floating slip fit on the inner end of the spindle body.

The wheel, with the inner bearing complete and the dust ring in place, is next mounted on the spindle. It is never necessary to force the large cone onto the spindle. The outer, or threaded, cone for that side, with its rollers assembled and properly packed with grease, is then screwed onto the outer end of the spindle. A right-hand threaded cone is used on the left spindle and a left-hand threaded cone on the right spindle, as with the old cup-and-cone bearings.

The adjusting cone should be run up on the spindle until the wheel seems to bind slightly. The wheel should then be turned a few times to make sure that all working parts are in good contact, then the adjusting cone should be backed off about one-fourth to one-half turn. This will be sufficient to allow the wheel to revolve freely but without end play.

Sometimes looseness in the spindle-body bushings may be mistaken for end play in the wheel bearings. To avoid any such mistake, insert a cold chisel or a screw driver between the jaw of the axle and the spindle to take up any play that might exist in the spindle bushings, and test the wheel for end play by working the wheel back and forth.

When the proper adjustment has been reached, the spindle washer and the nut should be replaced, the nut being drawn up tight and then cotter keyed as with the cup-and-cone bearings. Make sure that tightening the nut to the proper notch for the cotter key does not cause the bearings to bind; turning the wheel a few times just before the cotter key is inserted will determine this. The hub cap can then be filled with grease and replaced.

Periodic Inspection. Every three or four months the hub bearings should be cleaned out, repacked with fresh grease, and readjusted. The old grease should be thoroughly removed with kerosene or gasoline to make sure that no grit or metal particles remain in the hub to damage the bearings later. The rollers, cones, and cups should be carefully examined for pitting or other signs of wear.

SPRINGS

Replacing Center Bolts. We are now ready to inspect the front and rear springs. The first point is to make sure that the springs are correctly centered in the middle of the chassis frame. Sometimes the center bolts, which hold the leaves of the spring together and keep the spring from slipping from one side to the other, are broken. In such case, the spring leaves or the entire spring is likely to slide a little to one side and cause a slight tilt of the car. These springs are shown in Figs. 2 and 3.

If a center bolt is broken, it should be replaced with a new one. To do this work, it will be necessary for the mechanic to remove the entire spring assembly from the car. While the spring leaves are off the car, the surfaces of the springs should be sandpapered and covered with grease and graphite. The spring leaves will then slide freely over each other, thus making the car easy riding and reducing the likelihood of spring breakage.

Tightening Spring Clips. After replacing the springs on the car, the spring clips which hold the spring in place should be securely tightened, and then cotter pinned. After the car has been in use for some time, the leather pad between the top of the spring and the cross member of the chassis is squeezed down a little thinner. This loosens the springs, and it is therefore advisable to tighten the spring clips again after the car has been run from 500 to 1000 miles. Practically all cases of spring breakage through the middle of the spring are because the nuts on the spring clips have not been kept sufficiently tight. If this is done, the middle of the spring is kept as solid as one piece of metal with the cross member of the chassis and there is practically no bend or flexing at this point. It is then almost impossible to break the spring.

Shackles and Bushings. As the shackles at the ends of the springs come in contact with so much mud and grit, they, and also the bushings in the ends of the springs, are subjected to rapid wear. This wear will go on at an increasing rate if the worn parts are not replaced. It is a comparatively easy matter to drive out the old bushings from the ends of the springs and to drive in new ones; and about the only advisable repair on the spring shackles is to replace them with new ones. A very handy method

of replacing the spring bushings is shown in Fig. 44. A tube larger and longer than the bushing is placed on one side of the spring opposite the bushing to be removed. The new bushing is placed against the one to come out and the three parts are then caught between the jaws of a vise. As the jaws are screwed together, the new bushing forces the old one out of the spring; then the new bushing is reamed to size. A reamer is not expensive and should be included in the Ford mechanic's tool equipment to secure the best results. The late Fords are equipped with steel bushings in the springs, which require no reaming.

NEW SLEEVE

Fig. 44. Replacing Spring Bushings

OVERHAULING REAR-AXLE ASSEMBLY

Removing Rear-Axle Assembly. With the car jacked up at the frame, the rear-axle assembly is taken out as a unit. The two bolts and the cap screws holding the universal joint should be removed, the brake rods disconnected at the front end, and the spring shackles removed. The nuts on the front end of the radius rods near the universal joints, Fig. 45, are then removed, and after the nuts, Fig. 46, at the rear of the drive shaft holding the drive shaft in place are removed, the drive-shaft assembly can be moved toward the front. The wheels are then taken off. The

differential housing is held together by seven bolts, and, after removing the axle assembly from the car, these seven bolts should be removed. Put the nuts on the bolts and keep them together so that they can be found when needed again—in fact, this should be done with all the removed bolts and nuts. Whenever it is practical to put the nuts and bolts back in place after disassembling, it should be done, as much time will be saved. When the seven bolts have been removed, the two main parts of the housing

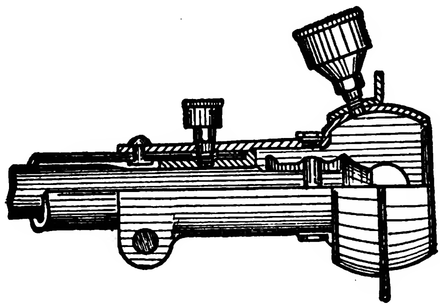


Fig. 45. Sectional View of Universal Joint

can be separated, disclosing the differential assembly and the bevel-gear driving system.

Bearings. The inner and the outer shaft bearings are in the housing. The sleeves forming the outer parts of these roller bearings are forced tightly into place, and if an attempt is made to remove them, they will be spoiled. They are split and are inserted at the factory with the split edges lapped; these sleeves may be installed with the use of a hammer. In removing these sleeves, they will be bent or sprung so much that they cannot be

restored to their original accuracy if a special puller made for this purpose is not used. If there is wear, the spoiling of the sleeves does not matter as it will be necessary to install new ones. There is no way to compensate for the wear in these bearings.

The rollers, however, come out easily. Because of the ample length and the extreme hardness of the rollers, they are likely to show less wear than the sleeves or the live axle shafts. The rollers bear directly on the live shafts, and as the shafts are necessarily rather soft, there will be no tendency toward brittleness.

Fig. 46. Sectional View of Rear Axle

The shafts may therefore be expected to show more wear than the other bearing parts. This naturally means new shafts.

The rear-axle bearings should then be inspected. If there is play in the parts of the inner roller bearings, the axle shafts may not stay exactly in the center of the axle housings. The amount of play should then be adjusted so that it is the same in one direction as in the other.

After getting the axle shafts centered in the middle of the axle housings, the rear nuts on the radius rods should be adjusted against the shoulders of the drive-shaft housing as shown in Fig. 45 near the universal joint. After having this adjustment correctly made, the nuts on the front end of the radius rod should then be tightened up securely. If these nuts are not kept

very tight, the radius rods will rattle and pound at this point. The hammering of metal against metal will also tend to cause crystallization and fatigue of the steel—a frequent cause of the breakage of Ford radius rods.

There is little use in half doing a replacement job of this kind. If there is looseness in the bearings and the sleeves and shafts show wear, both should be replaced. If only the sleeves are replaced, there will still be looseness caused by the wear of the shafts, which will quickly develop into more looseness. In short, it will not pay. While at it, put in whatever new parts are needed and make the job right. If this is done, there will be practically a new outfit.

The inner bearings next to the differential are the same size as the outer bearing but they will show less wear, as the outer bearing carries the weight of the car. However, the same principles apply to replacement of these bearings to compensate for the wear.

Wear of Thrust Rings. The thrust of the bevel driving gears creates a tendency for the large driving gears and the drive pinion to move apart. In other words, there is end thrust. This thrust operates against the thrust rings placed between the differential case and the rear-axle housing. The rings are of bronze or babbitt and are grooved to distribute the lubricant. The wear on the rings varies considerably, depending on the kind of roads on which the car is run, its load, the way it is driven, etc. If there is wear, the rings should be replaced with new ones.

This ring wear allows the bevel driving gear and its pinion to separate, consequently the teeth do not mesh as deeply as they should and there is a reduction of tooth surface in contact, wear of the teeth, inefficient operation, and noise. The bronze or the babbitt rings are placed between steel rings pinned to the differential cage and to the housing. Thus there are six rings: two floating rings, two rings on the differential cage (one on each side), and two rings on opposite sides of the axle housing.

Differential Gears. The differential gears are in a cage which carries the large bevel driving gear. The cage is made in two halves, and it can be taken apart readily. It is held by three studs and nuts, and once the nuts are removed, the spider

carrying the three small differential pinions is released, as the spider is held in place by the two castings that form the differential cage. This assembly is shown in Fig. 17. The pinion bearings should be examined for wear as more or less wear is likely to be found. The pinions themselves are of hardened steel and as a rule do not wear much; ordinarily they are found in good condition. Look at the bearings, however, and replace them if worn.

The live shafts and the large gears of the differential can be removed from the differential cage when the cage has been separated, which is done by pulling the shafts through the inside of the cage halves. The gears can be removed from the shafts after the shafts have been taken out by first forcing the gears farther on the shafts, permitting the removal of the split rings, and then sliding the gears off and leaving the keys in their keyway.

Ring Gear. The large driving, or master, gear is bolted to the differential spider, so that it can be replaced when it becomes worn. A new gear should be used if the teeth of the old one are chipped, burred, or worn.

Pinion Gear. The bevel driving pinion, Fig. 47, on the rear end of the propeller shaft is subject to greater wear than the ring gear because it has a smaller number of teeth and therefore a smaller surface over which the wear is distributed. So it is reasonable to look for some wear in the pinion even if the ring gear is in good condition. Do not use a pinion that shows signs of wear or is chipped, as it deteriorates quickly when once it starts to chip. Removing the pinion is accomplished by taking out the locking cotter pin that holds the castellated nut, after which the gear may be taken off with a gear puller.

Removing Drive Shaft from Housing. To remove the drive shaft from the housing, it is first necessary to remove the universal joint from the front end of the shaft. This universal joint is held on the shaft by a pin. The shaft end and the socket are square thus preventing turning. To remove the pin, two plugs—one on the top and one on the bottom of the shaft housing, near the universal joint—must first be removed. The bottom plug is shown in Fig. 48. The pin can then be driven out with a punch, after which the universal joint will come off when tapped slightly

with a hammer. The drive shaft can then be removed at the gear end of the shaft housing.

Drive-Pinion Bearings. Perhaps the most important bearings in the rear-axle assembly are those back of the drive pinion. There is a ball-thrust bearing and a roller bearing, and these should be thoroughly inspected to see that there is no lost motion; if there is, put in new bearings as the alignment of the gears depends on the fit here. Even if everything else is in perfect condition, looseness of these bearings will cause grinding and rapid wear when running.

Fig. 47. Driving Pinion and Ring Gear

Caution. If any of the gears have been broken or the teeth chipped, some of the pieces may have lodged between other teeth, and they will do a great deal of damage in this position.

Fig. 48. Universal Joint and Housing

The gears should therefore be carefully inspected and any chips removed.

Models Differ. In the late bearing models the seats in the central section of the axle housing carrying the inner bearings are of pressed steel fitted into the castings and held in place by the same rivets that hold the tubes to the housing castings. In the

early models these seats are formed directly in the castings by machining. This makes no difference in the disassembling or the assembling of the rear axle, but it is a point that is well to mention to avoid any confusion.

Adjustments. In overhauling a Ford rear axle, it should be borne in mind that while no means of adjusting the mesh of the gears is provided, all parts subject to wear are removable and renewable. The non-replaceable parts are not subject to wear. Therefore, if a rear axle is fitted with a new set of wearing parts, it will be in as good running condition as when it left the factory, providing the rear-axle housing has not been sprung or deformed by accident. All the parts are so easily obtained and installed that there is no reason for not making the necessary renewals. Saving money by not installing or renewing worn parts is very expensive economy, for it will lead not only to excessive wear of the parts in question but to the imposition of extra strains on other parts, causing them to wear more rapidly than they should.

For example, consider the thrust collars. If these collars are loose and other parts fit properly, there will be end play. This end play will allow the gears to work away from each other, placing extra wear on the teeth and increasing the thrust on the already worn collars and on the important bearings back of the driving pinion on the rear end of the propeller shaft.

Referring again to the bevel pinion, do not try to remove it by driving unless the propeller shaft is removed and stripped; trouble may follow. Use a wood block to drive the shaft out of the pinion so that the shaft end will not be damaged. The pinion is mounted on a taper shaft, and once it is started, it drops off. Do not use the Woodruff key—which will prevent the pinion from turning on the shaft—until it is examined to make sure that it is not battered or worn so that the pinion can move on the shaft. Be very sure that the key is in place when the pinion is put back; if not, there can be but one result—the car will not run.

Clean every individual part thoroughly and scrupulously. Do not leave a trace of old oil or dirt anywhere. When putting the parts together again, oil them, so there will be no danger of rusting the surface of the parts that are out of reach of the

oil in the housing. See that the spiral rollers of the roller bearings are thoroughly cleaned inside.

Reassembling. In reassembling the axle, make sure that all parts go together as they originally belonged. If anything binds or sticks or will not go in as it should, there is a reason. Find the reason and remove it instead of trying to use brute force. Make sure that every nut, every screw, and every bolt is properly tightened. At the same time, do not make the mistake of tightening nuts with so much force that the threads are partly stripped. Be sure that all cotter pins are replaced and that no passages designed for lubrication are blocked. Finally, see that this system is given a plentiful supply of the right lubricants. The Ford rear axle needs plenty of lubrication, and the owner should see that it gets it.

LUBRICATION SYSTEM

Importance of Lubrication. Lubrication was the subject of a very thorough investigation when the Ford unit power plant was designed because, while the main purpose was to obtain extreme manufacturing and operating simplicity, sufficient lubrication at all times had to be provided. From the viewpoint of an engineer, excessive lubrication of an internal-combustion engine will not have destructive influence, although accumulations of oil in the cylinders will coat the spark plugs and will impair, if not totally prevent, ignition. The unconsumed lubricant will collect upon the piston heads and the combustion chamber and will, with dust and foreign matters drawn through the carburetor air intake, become burnt and hardened by the heat and form carbon. While such a condition will lessen the efficiency of the motor, no actual damage will result unless the motor misfires in which event extra strains will be placed on the rear axle and the engine.

But if the oil supplied is insufficient, damage will certainly result, the most probable effect being the heating and scoring or even the melting of the babbitt-metal bearings of the crankshaft and the big ends of the connecting rods. Far more serious consequences may happen, such as a piston seizing in a cylinder, which may possibly buckle the crankshaft, bend or break a con-

necting rod, break a piston, or even puncture a hole in the crankcase, in the event that a connecting rod is broken.

When a bearing is not properly lubricated and it heats until the babbitt metal is softened or flows from the cage to the rod end retaining it, it is referred to as a *burnt-out* bearing. In other words, because of lack of oil, the friction so heats the metal that it becomes plastic and no longer supports the load upon it, taking a new shape and so enlarging that the shaft or rod has side or end play, which causes a noise of a peculiar and noticeable character. Obviously the only remedy in such a case is the replacement of the bearings—not a matter of great cost for parts, but quite an expense for labor and loss of service until the replacement is made. The standard labor price for this operation is $4.50.

Continuous Lubrication. Attention has been directed to the consequences of excessive and inefficient lubrication as adequate lubricity is imperative, and this cannot be obtained unless decided care is taken, despite the simplicity of the Ford system. In theory and in practice, the best results can always be obtained with machinery by feeding the lubricant in small quantities, constantly, and by having a supply which can be drawn upon for a considerable period of time. In motor-vehicle practice, the last-mentioned requirement is very important, for frequent renewals would demand an amount of care that would be objectionable to the drivers. The purpose of the design of the Ford engine was to have a system which would feed oil continuously and which could be operated for a considerable time or distance with one supply, the replenishments depending largely upon the use made of the car.

Simplicity and economy demand that the system have the fewest parts practicable, and efficiency requires that the engine be fully lubricated, especially as many of the owners have little or no knowledge of mechanics and might, because of ignorance, neglect conditions that would receive attention from those more experienced.

Parts of Lubrication System. A sectional view of the Ford motor, Fig. 49, shows the lubrication system. As previously stated, the engine block and the head are cast separately, the cylinder block forming the upper portion of the crankcase, while

the lower half of the crankcase is of pressed steel, about $\frac{1}{16}$ inch thick, extended back of the engine to form the bottom section of the flywheel and gear-set case. In this pressed-steel section is an opening extending from a point just forward of the front wall of No. 1 cylinder to a point directly beneath the wall between cylinders 3 and 4. This opening is $13\frac{5}{8}$ inches long and $5\frac{1}{4}$ inches wide and is surrounded by a raised edge, and a ring that is $\frac{3}{8}$ inch high and $\frac{5}{8}$ inch wide.

Oil Troughs. The opening is closed by a pressed-steel plate, or cover, $15\frac{1}{3}$ inches long and $6\frac{7}{8}$ inches wide, bolted on with a gasket between it and the case, thus making an oil-tight joint, the lap being about $\frac{3}{4}$ inch. The plate is slightly curved to conform with the general shape of the crankcase, and in the plate are three transverse troughs $\frac{9}{16}$ inch deep that are, when the cover is in place, directly under the caps of the connecting rods of the first three pistons of the engine. These can be noted in Fig. 49.

Oil Reservoir. From a point just back of the rear portion of the ring about the opening, the crankcase is sharply bellied, or enlarged, to form a housing for the flywheel, and directly under the flywheel there is a cone-shaped pocket. From this the crankcase bottom rises to a point slightly above the level of the connecting-rod caps. From the ring rearward the bell housing of the flywheel forms the reservoir in which the oil is carried.

Correct Level of Oil. There are two drain cocks located in the rear of this oil reservoir, so that the amount of oil contained in the tank can be ascertained. The motor must never be run until the oil is below the level of the bottom cock. When starting on a trip, the reservoir should be filled so that the oil will run out of the top cock. Be sure that dirt has not obstructed the openings in these cocks, as they are subjected to a great deal of road dirt. To secure the best results, the oil level should be about halfway between the two gage cocks. Were there exact knowledge of the quantity of oil required to fill the crankcase between the two drain cocks and were half of this oil placed in the engine base, perhaps the proper level would be reached, but there is no way of determining the consumption of the lubricant other than to learn if there is a flow from the lower cock.

Fig. 49. Power Plant Lubrication System

It should be remembered that the crankcase of the engine is not obstructed below the level of the main bearings from end to end and that the flywheel edge as it revolves is about $\frac{1}{2}$ inch above the inclined bottom of the case behind it. The engine case when full will contain about 4 quarts of oil, the lubricant being $\frac{15}{16}$ inch deep in the troughs behind the three front connecting rods in the bottom cover plate and slightly below the level of the cover plate. The troughs are supposed to contain sufficient oil to permit the connecting rods to dip into it as they revolve. When the machine is ascending or descending grades, the flow of the lubricant in the troughs must be either backward or forward, and in volume depending upon the angle of the grade.

Circulation of Oil. Assuming that the machine is being driven on a level surface, the condition of the oil in the crankcase

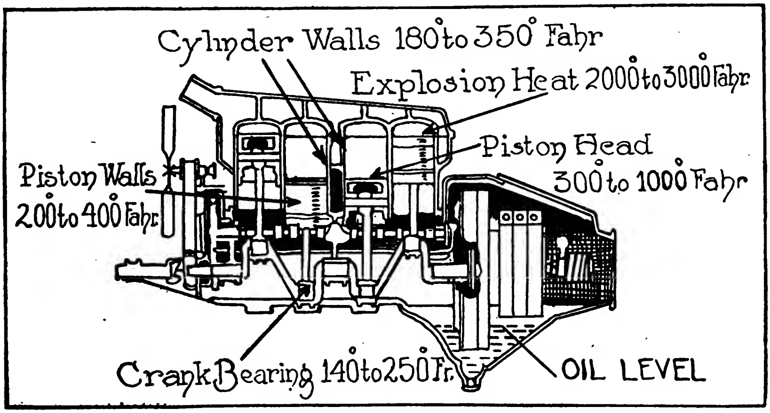


Fig. 50. Motor Temperature and Lubrication

is similar to that shown in Fig. 50. About $\frac{1}{3}$ of the diameter of the flywheel is submerged in the oil; and the lower part of the three contracting bands that encircle the revolving planetary-gear set, the peripheries of the high- and the low-speed drums, and the surface brake drum are sprayed with oil from the flywheel. At every revolution of the crankshaft, the caps of the three forward connecting rods strike the lubricant in the troughs, while the cap of the rear connecting rod strikes a heavy spray of oil in the reservoir ahead of the flywheel. The approximate temperature of the various motor parts is also shown in Fig. 50.

As the engine turns, the sweep of the connecting rods into the oil creates a splash that throws the lubricant from the left to the right side of the crankcase, and as the ends of the rods are swung through the space beneath the cylinders, the greater part of the oil is thrown off in the form of a spray. This is the result anticipated in all splash systems. The revolution of the gear set does nothing more than plentifully lubricate the pinions and the gears, and the degree of the lubrication is greatly in excess of the actual needs, but this is not a condition that can be criticized as it is insurance against wear.

As the flywheel revolves in the oil, it carries upward considerable lubricant, which is thrown off against the right side of the crankcase and the top of the flywheel housing. A small funnel is attached to the inside of the crankcase, Fig. 49. This funnel is directly in the line of the movement of the flywheel assembly, and the legs of the sixteen magneto magnets, clamped to the flywheel, serve as paddles and throw the oil up in considerable quantity when they rise above the surface of the lubricant; part of this flows into the funnel. The funnel is connected with a brass tube that leads along the inside of the crankcase and all the oil collected is carried forward to the gears at the front of the motor in the timing-gear case. When the crankcase is filled to the level of the highest drain cock, the volume of the oil circulated will be the greatest, and with the engine running at 1500 r.p.m., the circulation will be at the rate of about 2 quarts per minute. As the oil is consumed and the level is lowered, the volume of the oil circulated will decrease—probably to less than half the maximum of 2 quarts, and when below the lower drain cock, the circulation lessens rapidly. Of course, there are other conditions that influence the oil circulation, the character of the oil—for a heavier lubricant will not be as thoroughly distributed, and a lighter oil will be carried in a larger volume—the heat of the engine, temperature of the air, all are factors that must be considered.

Filling the Troughs. As the oil is carried forward in the tube, it floods the timing gears and then flows into the bottom of the crankcase and over the forward end pan, filling the pool beneath the connecting rods. The connecting rods dip into the

oil about $\frac{1}{2}$ inch when the piston is on lower dead center. In recently built chassis, openings are made in the sides of the oil troughs, varying from $\frac{1}{16}$ to $\frac{1}{8}$ inch, to reduce the depth of the oil beneath the connecting rods, but obviously the flow is greatly dependent upon the heat of the engine, the grade and viscosity of the oil, and the volume supplied. As the openings are not uniform in width, one cannot determine what will be the actual oil depth in the troughs in any given operating condition. The oil thrown off by the big ends of the connecting rods lubricates the center and the rear main bearings, the wristpins, cylinders, pistons, cams, and valve tappets.

Viscosity of Oils. The oil used for lubricating purposes is intended to form a film between two moving surfaces, and by preventing actual contact of the parts it minimizes friction. The fluidity of oil is spoken of as its viscosity and is measured by the time required for a given volume at a given pressure to pass through a standard aperture. The time is expressed in seconds and the reading is usually taken at 200 to 212°F. The range of the test of oils used in internal-combustion motors is from 180 seconds for a light or medium oil to 2300 seconds for an extremely heavy oil. Oils of less than 180 have insufficient body to lubricate satisfactorily and those of more than 800 are unsatisfactory because the fuel consumption is increased. It has been found by laboratory tests that maximum results can be obtained in the cylinder with oil having a viscosity of 180. This affords the greatest horsepower for the amount of fuel consumed.

Formation of Carbon. Oil from the lubrication of the pistons and the cylinders is splashed on the lower cylinder walls and is carried upward and spread over the cylinder walls to the height of the piston stroke by the pistons and the piston rings. A certain quantity is thrown off the pistons by the upward strokes and is projected onto the walls of the combustion chambers. If the quantity thrown off is small and the mixture is "lean" and is consumed rapidly, the oil will be practically all burned by the explosion and there will be no appreciable deposit of carbon. But when the quantity is large and the heat of the explosion does not consume it as readily, the vaporized portion is exhausted with the gases as smoke and the remainder is left on the walls as the heavy

end-products of destructive distillation. These are reduced by the intense heat into a cumulative incrustation that is generally referred to as carbon deposits.

Effects of Carbon. The deposits of carbon in the combustion chamber, on the valves and seats, the spark plugs, and the piston heads decrease the efficiency of the motor; and while burning a mixture of fuel that will as far as possible secure complete combustion and thorough scavenging of the cylinders will undoubtedly have some influence, carbonization will eventually result. Yet the use of a good oil will greatly lengthen the period of service between removals of carbon. Sooted spark plugs, necessitating frequent cleaning and causing faulty ignition and loss of power; carbonized valves and valve ports, followed by leakage, loss of compression, dilution of fuel, and excessive fuel consumption; preignition from the points of carbon becoming incandescent—all these are among the certain results of carbonization.

Cylinder Oil Film. The cylinders of the engine are usually bored to have the same diameter the entire length. The pistons are generally turned to have a slightly smaller diameter at the top, or head, to allow for expansion. The cylinder walls will be kept reasonably cool by the circulation of the water, but the pistons are cooled only by the admission of cool fuel and by the splash of oil into the cylinders. The clearance—the space allowed between the walls of the pistons and the cylinder—is filled by the piston rings, which are formed to be slightly larger than the cylinders and are compressed into the ring grooves. If the cylinders are true and the piston rings fit perfectly, the latter will prevent the escape of the gas during the compression and the explosion strokes, the film of oil between the rings and the cylinder walls forming an oil seal. The lubricant that best serves is that which affords the most perfect seal and the greatest degree of lubricity.

CARBURETION SYSTEM

Importance of Correct Mixture. Many mechanics do not realize the importance of a perfect carburetor adjustment. Different adjustments should be used when the car is driven under certain conditions. For instance, a certain amount of gasoline can

be saved if the mixture is thinned down when the car is being driven between towns and a regular speed can be maintained. The pick-up will not be quite so good, but this sacrifice can be made in view of the saving in gasoline.

The experienced driver can tell from the sound of the motor whether it is laboring with an over-rich gas mixture or whether it is "starving" for want of a mixture sufficiently rich to give the motor full power and to obtain gasoline efficiency.

Troubles Misleading. Many ignition troubles have symptoms similar to those of carburetor troubles, and it sometimes takes a little time to determine which is at fault, the carburetor or the ignition system. For example, a poorly adjusted carburetor and a weak magneto have similar symptoms, as a weak magneto will not satisfactorily fire a charge that is either too rich or too lean.

If the car is taken out on the road and run at about 15 m.p.h., the carburetor can be adjusted so closely that the car will run perfectly at that speed. As soon as the car is stopped and again started, the same trouble may recur, and the motor may misfire a great deal.

Back Fire in Intake Manifold. Too thin a mixture will make the motor spit-back or back-fire in the intake manifold and into the carburetor. The layman and even the mechanic will often wonder how the gas in the intake manifold and in the carburetor can be burned as the explosion takes place in the cylinder long after the intake valve has closed. It must be remembered that a thin mixture burns much slower than either the proper mixture or the rich one.

There is a lapse in time of only a small fraction of a second between one explosion and the opening of the intake valve at the beginning of the next cycle when the motor is running at 1200 revolutions per minute, or 20 revolutions per second. As there is one explosion in each cylinder in every two revolutions, 10 explosions will occur in that cylinder in 1 second; in other words, $\frac{1}{10}$ second will be the time allowed for the completion of the four strokes of the cycle. This allows $\frac{1}{40}$ second for each stroke of the piston. When the spark occurs, the thin mixture continues to burn through the power and the exhaust strokes, and it is still aflame when the intake valve opens at the beginning of the

next cycle. This gas has then been burning through two strokes of the cycle, or $\frac{1}{20}$ second, if the motor is running at 1200 revolutions per minute. The gas in the intake manifold is ignited by this flame.

Carburetor Adjustments. There are but two parts that can be adjusted on the Ford carburetor, the float, which needs very little adjustment, and the needle valve. In order to adjust the float, it is necessary to take the carburetor apart. The float,

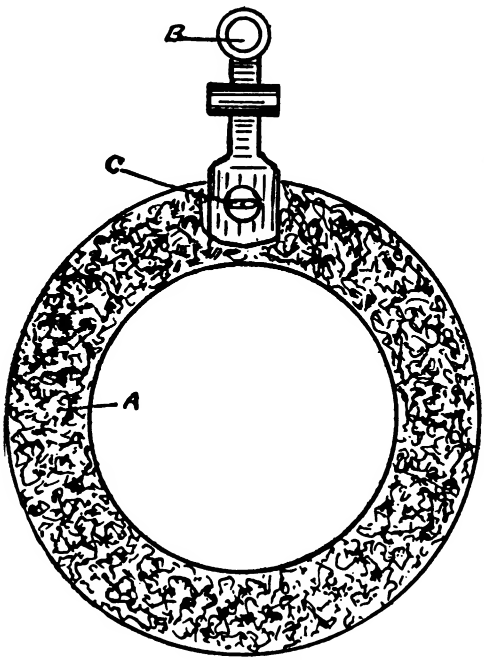


Fig. 51. Carburetor Float

Fig. 51, is made of cork and is well shellacked so that the gasoline will not be absorbed and cause the float to be heavy, or waterlogged. The float closes the valve that allows the gasoline to enter the carburetor from the gasoline tank, and if the float is waterlogged, the valve will not close when the gasoline has reached its proper level. This will cause the carburetor to leak when the car is standing and permit a rich mixture when the motor is running. To remedy this trouble, the float must be thoroughly dried and a fresh coat of shellac applied; or a new

float may be installed. The float arm must be bent if the gasoline level in the float is not at the proper point. Fig. 52 is a sectional view of the Kingston carburetor, while the Holley carburetor is shown in Fig. 53. The gasoline level must be high enough to allow the gasoline to come just below the top end of the spray nozzle. If this level is low, the motor will start hard. If the float valve *C*, Fig. 52, does not seat properly, or leaks from any cause, the carburetor will leak just as though the float was water-logged. The pin *B* holds the float and the float lever in proper relation to the float valve *C*. The gasoline, or needle-valve, adjustment is made by turning the needle *J*, the adjustment rod extending to the dash of the car. If the needle is turned to the right, or clockwise, the mixture will be made thinner; if turned to the left, or anti-clockwise, a richer mixture will result.

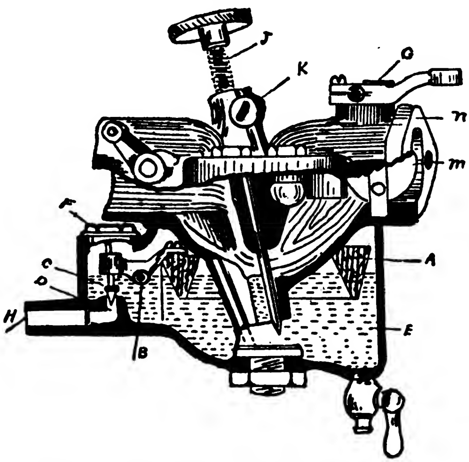
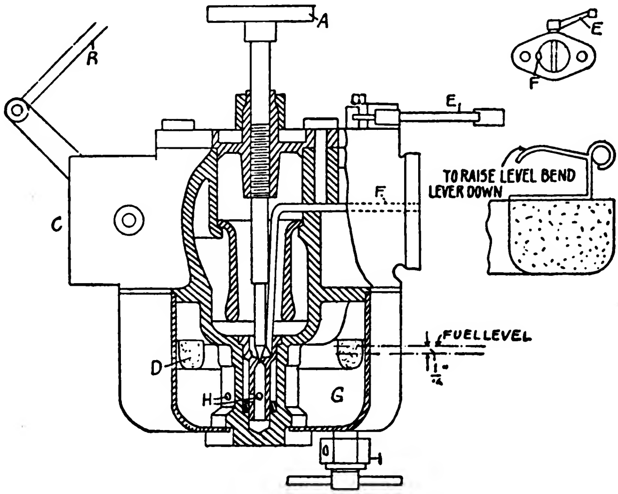


Fig. 52. Sectional View of Kingston Carburetor

Care of Gasoline Line. The gasoline line is a very important part of the carburetion system. It is sometimes clogged or obstructed with foreign material, thus preventing the gasoline from flowing properly to the carburetor. Lack of gasoline will cause the motor to spit-back in the intake manifold just as it would if the nozzle was set for too thin a mixture. If the gasoline line is obstructed, the motor will generally run without missing at low speeds, but when speeded up, it will start to miss. This is due to the fact that there is not enough gasoline flowing to the carburetor to replace the gasoline that the motor has consumed.

Care of Spray Nozzle. The carburetor spray nozzle has a very small opening and therefore a particle of some foreign substance can easily clog up this opening. This will cause the motor to misfire and slow up when the throttle is opened, the motor acting much as if there was a clogged-up gasoline line. This

occurs because the motor requires a great deal more gasoline when running fast than when idling. The obstruction can generally be removed by opening the needle valve a few turns and then opening the throttle several times in rapid succession; this draws the dirt or other foreign matter through the spray nozzle. The needle must then be turned back to the original position. If this does not remove the obstruction, it will be necessary to drain



Section of Holley Carburetor: A, Needle Valve; B, Choker Rod; C, Auxiliary Air Intake; D, Float; E, Throttle Lever; F, Slow Speed Supply Tube; G, Float Chamber; H, Supply Holes to Needle Valve; I, Drain.

Fig. 53. Sectional View of Holley Carburetor

the carburetor, which, after it is removed from the car, should be thoroughly cleaned.

Hot-Air Pipe. The hot-air pipe furnishes a supply of warm air to the carburetor and vaporizes the fuel. It is advisable to remove the hot-air tube during the summer months, but this tube must be on the car during the winter months.

Throttle Adjustment. If the motor runs too fast when the throttle is fully closed, it is necessary to adjust the throttle stop screw. The lock screw that keeps the throttle-adjusting screw from turning, Fig. 52, should first be loosened. The throttle screw is then turned out—anti-clockwise—until the motor slows up to the desired speed. The lock screw is then tightened so that the adjustment will be permanent.

Setting Carburetor for Heavy Fuels. The old Holley carburetors were fitted with a strangling tube $\frac{13}{16}$ inch in diameter at the throat. This strangler, or mixing tube, was satisfactory for the high-grade fuels of a few years ago, but it does not handle the present fuel as it should. This mixing tube, Fig. 54, can be replaced with a tube $\frac{23}{32}$ inch in diameter at the throat for the proper mixing of the present heavy fuels. The smaller tube causes a greater velocity of the gases through the mixing chamber, and therefore there is a better mixture when the gas enters the cylinders, which results in greater mileage and power.

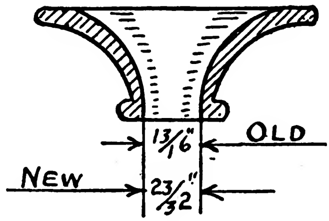


Fig. 54. Carburetor Mixing Tube

TROUBLE SHOOTING

KNOCKS IN MOTOR

Q. If the motor has a rather sharp slap or knock, when the throttle is quickly opened, what may be the trouble?

A. This symptom is indicative of piston slap, fuel knock, or carbon formation. If the car has not run many thousands of miles, it would be advisable to eliminate the possibilities of the piston slap. One of the spark plugs should then be removed and inspected and the combustion chamber examined through the spark-plug hole to find out what condition the combustion chamber is in. If there is a heavy coating of carbon, the cylinder head should be removed and the carbon scraped off, or it may be removed by the oxygen process.

Q. If a dull heavy knock is heard when pulling through sand or up a hill, what does this indicate?

A. This knock generally indicates that the main bearings are loose, and they should be inspected as soon as possible, as operating the motor with loose main bearings will cause the crankshaft pins to wear considerably and there is also a possibility of the crankshaft being sprung or broken.

Q. If a knock is present when the throttle is closed or when the car is pulling the motor, such as going down a hill, what does this indicate?

A. When a knock is produced under these conditions, it generally is caused by a loose connecting rod. The particular rod that is loose can be located by shorting the spark plugs with a hammer or a screw driver. The motor should be running idle when this test is made. When a double knock is heard, the connecting rod in that particular cylinder is loose. This is very easily detected after a little practice.

Q. If a sharp knock is present when the throttle is quickly opened; the pistons fit perfectly; there is no carbon deposit; and all bearings are tight—what then should be inspected?

A. About the only other condition that would cause the motor to knock is a spark advanced too far or an overheated motor. Either of these will cause the explosion to occur early, and this early explosion will drive the skirt of the piston against the cylinder with great force, producing a knock similar to the piston slap. If this trouble is due to the spark lever being advanced too far, the knock will usually die out when the lever is retarded.

GENERAL REPAIRS

Q. How often should the Timken wheel bearings be removed from a Ford to be greased and cleaned?

A. The Ford manual gives the instruction to remove the front wheel bearings every 500 miles so that the bearings may be cleaned and repacked with grease. This, however, applies to the ball-bearing type, which is the regular equipment on all open cars. For the closed cars, which are Timken equipped, however, it is necessary to remove the front wheel bearings only about every 2000 miles, washing out the bearings thoroughly with kerosene and repacking with fresh grease.

Q. When a grinding noise is present, seemingly in the transmission, what is the cause?

A. This trouble is generally due to worn triple-gear bushings in the transmission. These worn bushings cause the gears to grind considerably as the teeth do not mesh as they should, especially when the low-speed or the reverse pedal is depressed.

Q. If a continual thumping noise is heard and it seems to come from the rear axle, what parts should be inspected to locate this trouble?

A. The cause of this thump is undoubtedly a chipped tooth on the ring gear. The chip may have lodged between two teeth, in which case it will cause a thump every time it passes by the pinion. This chip should be removed at once, as it is sure to spring the differential housing and cause much damage if allowed to remain in this position.

Q. What causes the motor to miss on two cylinders and at the same time back-fire into the intake manifold?

A. If the timer has been replaced, it is quite likely that the wires have not been connected properly to the timer terminals. If this is the case, the spark will occur in two cylinders just as the piston starts down on the intake stroke instead of when the piston is just starting down on the power stroke, thus giving a back-fire in the intake manifold. When these pistons again come up on the compression stroke and are ready to fire, no spark will occur in the cylinders as the spark has already taken place one revolution earlier; therefore, the two cylinders will miss.

Q. What is the trouble when the motor will not idle down or pull when operating in low speed?

A. This trouble is undoubtedly due to either the float level being too low; air leaks around the valve stem, Fig. 31; or air leaks in the intake manifold. In order to locate leaks in the manifold, a rag moistened with gasoline should be laid over the connections between the manifold and the cylinder block, or gasoline may be poured sparingly on the manifold. If the motor increases in speed, it is a sign that the manifold leaks at the place where the rag was held when the speed of the motor increased.

Q. Is it possible to remove one or two tubes from the Ford radiator and replace them with new ones?

A. It is possible to remove these tubes, although the process necessitates a great deal of work. The head, or tank, must be unsoldered at the back, removing the rear section so that the upper ends of the tubes may be unsoldered. The tank at the bottom of the radiator must also be opened up so that the old tubes can be unsoldered and the new tubes inserted. If possible, the old tubes should be repaired; this will generally eliminate considerable work.

Q. How tight should the crankshaft bearings of a motor be adjusted?

A. Bearings should never be adjusted on any motor so that the average man cannot crank it with ease. Suppose the bearings are tightly placed; it will then be necessary for them to wear a certain amount before a film of oil on a bearing can be properly formed. After the car is run a few thousand miles, the bearings are worn to fit more correctly than they could be scraped by a first-class mechanic. A very tight bearing will also loosen quicker than a snug bearing and will naturally cause more trouble. If the bearings are adjusted so that the piston will drop by its own weight—if the crankshaft and the rod are on the bench—you will have no trouble with bearing knocks and the motor can be immediately operated without fear of burning out the bearings.

Q. How should you proceed to reline the Ford transmission bands?

A. To reline the transmission bands, it is necessary to remove the cover of the transmission and flywheel case. The bands are then moved back, turned around, and lifted out. The new lining is then riveted in place on each band, preferably with split rivets. In replacing the bands, it is necessary to wire the ends together after they have been placed on the transmission drums so that the pedal bars will engage the ends of these bands when the cover is set in place. After the transmission cover is tightly turned in place, the pedals should be adjusted by means of the adjusting nuts on the pedal bars and on the transmission case, this adjustment being made through the opening made by removing the inspection cover on the transmission. These bands can be exchanged at small cost for new bands.

Q. How is the ring gear adjusted?

A. While there is no adjustment of the ring, or bevel, gear on the Ford car, if the thrust bearings are in good condition and not worn, the gears will mesh properly; if, however, these thrust bearings are worn, they should be replaced as the gears will wear out rapidly if the car is operated when they are improperly meshed.

Q. How much clearance should be allowed between the ends of the piston rings?

A. A clearance of 0.003 inch to each inch of piston diameter should be allowed between the ends of the piston rings. As the

Ford motor has a bore of $3\frac{3}{4}$ inches, a clearance of from 0.012 to 0.015 should be allowed. This, however, is a general rule and the Ford Motor Company recommends a clearance of 0.012 between the ends of the upper ring, 0.008 between the ends of the second ring, and from 0.004 to 0.006 between the ends of the third, or bottom, ring.

Q. How much clearance should be allowed between the piston and cylinder when new pistons are being fitted?

A. A clearance of 0.00075 to 0.001 inch for each inch of piston diameter should be allowed at the top of the piston, using cast iron as the material for the pistons. When aluminum is used, 0.0025 to 0.003 inch should be allowed as this metal expands much more than cast iron.

FORD 1921 MODEL TOURING CAR

FORD CONSTRUCTION AND REPAIR

PART II

ELECTRICAL SYSTEM

Elementary Electrical Principles. All Ford cars are now equipped with an electric starting and lighting system at the factory. The mounting of the starter and generator is shown in Fig. 55. In order to understand this system, a few characteristics of an electric current will first be taken up.

There are three qualities in an electrical current that must be understood, as the actions of these qualities determine to a great extent the trouble in the system:

The *volt* is the unit of electrical pressure, which may be likened to the pressure in a water-supply system that forces the water through a pipe.

The *ampere* is the amount of current that flows through a circuit, which may be compared to the amount of water that flows through a pipe.

The *ohm* is the unit of electrical resistance which tends to hold back the amperes flowing through a circuit and which may be compared to the resistance in the water pipe that tends to hold back the water.

It is therefore evident that if the voltage of a circuit is increased, there will be more amperes flowing through the circuit, just as when the pressure in the water-supply system is increased, there is a greater amount of water flowing through the pipes. If the size of a wire is increased, a greater amount of current will flow, just as more water will flow through a 2-inch pipe than through a 1-inch pipe, the pressure being the same in both cases. It is therefore necessary to use wires of different sizes for different circuits in the electrical system according to the number of amperes necessary to operate the particular instrument to which the wires connect. For instance, the starter cable is No. 0, while the cable

d for the horn is No. 18; the pressure, or voltage, on the circuit does not exactly determine the size of wire necessary. The

Fig. 55. Ford Motor Showing Mounting of Starter and Generator

greater the voltage, the smaller must be the wire to handle a given current, as a high voltage would force a greater amount of

current through a given resistance. On the other hand, if a higher amperage is needed, the wire must be larger. If the wire is too small for a certain current discharge, it will sometimes become so hot that it will burn or fuse and cause an open circuit.

Insulation. All cables and wires running from the battery to the various instruments and from the magneto must be covered with a suitable form of insulation to prevent short-circuits. Wires carrying low-voltage current, such as used in the Ford car on the starting and lighting system, do not need so heavy an insulation as is necessary on the spark-plug cables. The high-tension, or spark-plug, cables carry a very high voltage, ranging

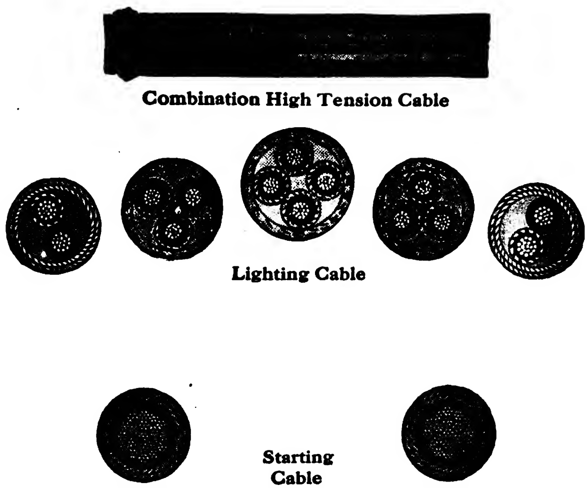


Fig. 56. Types of Cables Employed in Automobile Electrical Equipment

from 6000 to 18,000, and it is therefore necessary to use a heavy insulating material of good grade on these wires. Fig. 56 shows the insulation on the various wires. A water pipe carrying a pressure of 100 pounds per square inch would necessarily need to be stronger than one carrying 10 pounds per square inch. This is equally true of the electrical system, using the voltage carried as the determining factor when the thickness of the insulation is to be ascertained.

Magnetism. When current flows through a conductor, magnetism, or magnetic lines of force, flows around this conductor, Fig. 57. If this conductor, which is generally a wire, is wrapped

around a soft-iron core, Fig. 58, and a current is allowed to flow through this conductor, this core becomes a strong electromagnet. The strength of this electromagnet depends entirely upon the ampere turns in the coil. An *ampere turn* is 1 turn of wire through which 1 ampere is flowing. If there are 100 turns and 4 amperes flow through the circuit, there are 400 ampere turns in the coil, and the magnet is four times as strong as if only one ampere were flowing. If this soft-iron core was replaced with a piece of steel, the magnet would be permanent after it was once magnetized by the current flowing through the coil. When the soft-iron core is used, the magnetism is retained only as long as the current flows. The electromagnet is used in the Ford coils to operate the ignition, in the starter and the generator fields, and in charging magnets in the shop or on the car.

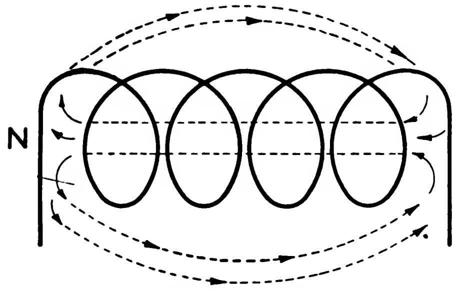


Fig. 57. Magnetism Around the Conductor

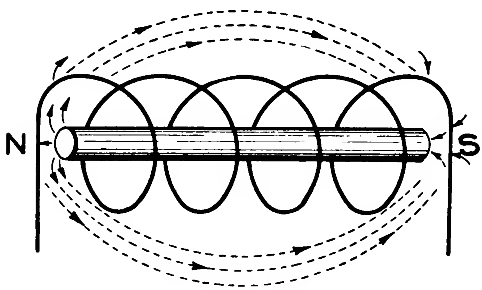


Fig. 58. Construction of Electromagnet

IGNITION SYSTEM

The ignition system consists of a magneto or a battery as a source of current supply; spark, or induction, coils; a timer; and a set of spark plugs.

Induction Coils. The Ford induction, or ignition, coils are located in the coil box on the dash of the car. On the earlier models—which were not equipped with the starting system at the factory—an ignition switch was placed on the outside of this box. On the late models the ignition switch is located on the cowl and forms a part of the lighting switch. There are four coils in this

box, Fig. 59 showing the box in cross section. Each coil furnishes a spark to each cylinder of the motor.

If the electromagnet is wound with a number of turns of fine wire over the primary winding, Fig. 59, a transformer is produced. A spark of very high voltage will be induced in this winding

Fig. 59. Cross-Section of Coil-Box Unit

when the circuit in the primary winding is broken. The current induced in this secondary winding is as many times stronger than that flowing in the primary winding as the number of turns of wire in the secondary is greater than the number of turns in the primary. For instance, if there are 100 turns in the primary winding and 100,000 turns in the secondary winding, the voltage

of this secondary current will be 1000 times the voltage of the primary current, if the resistance in the external circuit of the secondary is not changed.

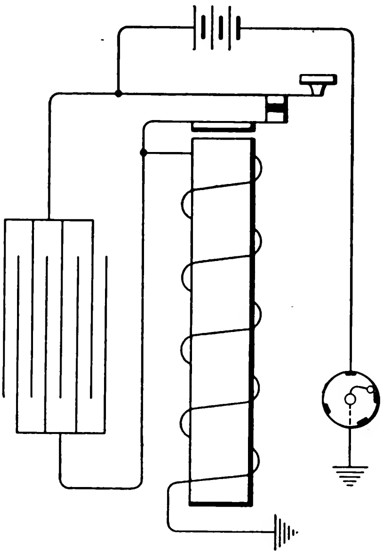


Fig. 60. Connection of Condenser in the Coil

In the case of an ignition coil, the change in voltage is very great as the current from the secondary winding must have sufficient pressure, or voltage, to jump the gap at the spark plug. This current has a very low amperage, however, for it never exceeds $\frac{2}{10}$ ampere and generally it is about $\frac{1}{100}$ ampere. The voltage finally depends on the compression and the spark-plug gap.

Vibrator. The vibrator is used to cause frequent continuous breaking of the primary circuit, as a strong current is induced in the secondary winding when the circuit of the primary is broken. By referring to Figs. 59 and 60, it will be noted that the vibrator is directly above the end of the core. When the core becomes a magnet, it will attract the vibrator *A*, pulling it down and opening the circuit at the point *B*. The opening of this primary circuit causes the core to lose its magnetism, and the vibrator is then drawn up by a spring, again closing the circuit at the points *B*, and the core again becomes magnetized. This series of events continues at the rate of many times a second with the result that the core of the coil alternately becomes a magnet and then an ordinary unmagnetized piece of iron. When the primary circuit is broken the magnetism instantly disappears causing a secondary current to be induced in the secondary winding, and each impulse

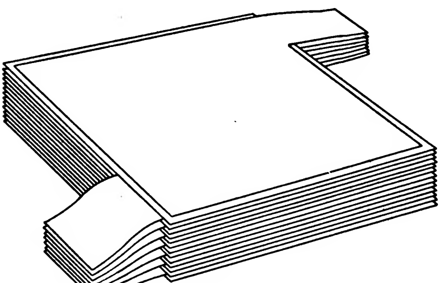


Fig. 61. Construction of the Condenser

gives a current of sufficient strength to jump the gap between the points of the spark plug.

Condenser. The condenser, Figs. 60 and 61, acts as a reservoir in storing up, or absorbing, a certain portion of the current at the time the points separate. It may be likened to a surge tank or diaphragm, Fig. 62, which allows the water in a water system to move into a by-pass when the main outlet is quickly shut, thereby preventing the breakage of the water pipe. The condenser is contained in the coil unit and is composed of sheets of tin foil and paraffin paper in alternate layers; every other sheet of tin foil is connected to one of the vibrator points; the remaining sheets are connected to the other vibrator point. The con-

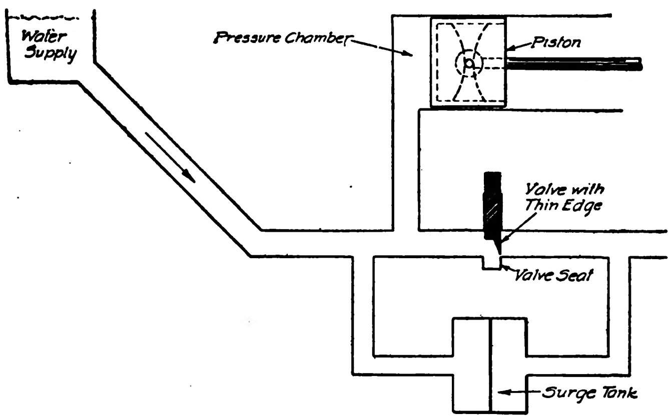


Fig. 62. Diagram Showing Hydraulic Analogy of Ignition System

denser prevents the vibrator points from burning rapidly and at the same time causes the magnetism to disappear quickly. A certain amount of current is induced in the primary winding at the time the circuit is broken, and this eddy current tends to again magnetize the core. This continuous action, if unremedied, would prevent the quick demagnetization of the core and cause a very inefficient secondary current. The condenser absorbs the eddy currents, thereby allowing a strong spark to be produced at the spark plug. It is almost a sure sign that the condenser is defective when the vibrator points start to burn and a white spark appears at these points. If, after examining the points and replacing them with a new set, the spark still continues, it is evi-

dent that the condenser has broken down. It will then be necessary to install a new coil as the condenser cannot be repaired.

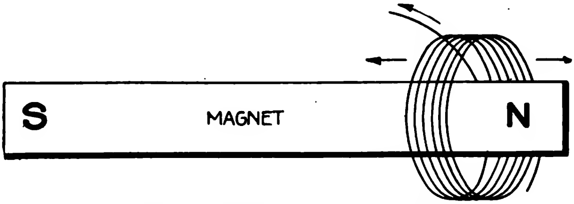


Fig. 63. Principle of Induced Current

Ford Magneto. If magnetic lines of force are cut by a coil, a current is induced in the coil. By referring to Fig. 63 it will be noted that the coil is being moved backward and forward on

Fig. 64. Magneto Coils and Magnets

the end of a permanent magnet. This action induces a current in the coil in the reverse manner that a soft-iron core was made an electromagnet by allowing a current to flow through the coil. A Ford magneto utilizes this same principle in generating a current for ignition —for ignition and lights on early models. Fig. 64 shows the magneto coils and their relation to the magnets. There are sixteen stationary coils and sixteen magnets that are fastened on the flywheel and revolve at a distance of $\frac{1}{32}$ inch from the

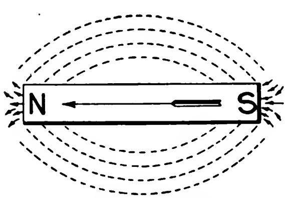


Fig. 65. Path of Magnetic Lines of Force

cores of these coils. The rapid cutting of these magnetic lines of force by the coils—the magnets moving—induces a current in the coils of variable voltage, the voltage depending upon the speed at

TABLE I

Output of Early Ford Magneto at Various Speeds

R.P.M.	Volts	Amperes	R.P.M.	Volts	Amperes
200	8.0	3	800	20.0	—
300	9.2	—	900	22.8	—
400	12.2	—	1000	24.3	—
500	14.2	—	1200	27.0	—
600	16.4	—	1500	30.0	5
700	18.8	—			

which the motor is operating. The amperage also varies with the speed of the motor but does not vary as much as the voltage. The magneto will generate sufficient current to operate the ignition satisfactorily at all motor speeds.

Fig. 66. Mounting of the Magnets

Magnetic lines of force pass from the north pole to the south pole of a magnet, Fig. 65. When these lines of force travel through a coil in a certain direction, the current will flow from that coil from a certain terminal in one direction only. If the

direction of these lines of force is changed, the direction of the induced flow of current will also be changed. The horseshoe magnets form a magnetic circuit between their poles; they are mounted with like poles together, Fig. 66. Small steel plates are mounted at the ends of the magnets so that the lines of force will pass through the cores of the coils a greater length of time than if the ends of the magnets were bare. Alternate coils are wound in opposite directions so that a current of the same polarity will be induced in all sixteen coils at the same time. When the south poles of the magnets are opposite a coil that is wound in one direction, Fig. 67, the current will flow in the direction indicated by the arrows. North lines of force are then flowing through the core of the adjacent coil, and as this coil is wound in the opposite direction to that of the first coil, the current will flow in the same direction. When the magnets are turned one-sixteenth of a revolution, north magnetic lines of force will be flowing through the first coil and south magnetic lines through the second coil. The direction of the induced current will then be changed, this reversal taking place sixteen times in every revolution. This position is shown in Fig. 68.

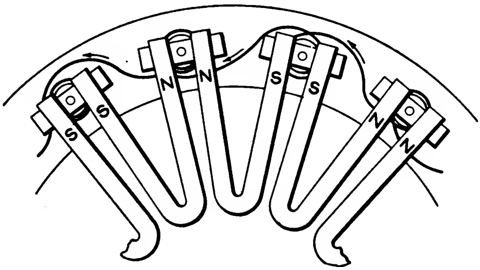


Fig. 67. Current Induced in One Direction

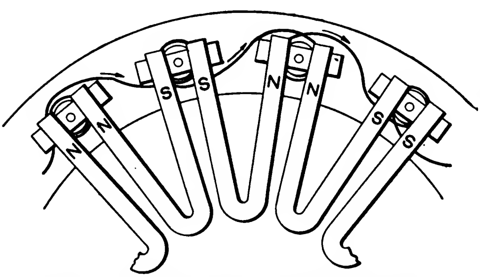


Fig. 68. Current Induced in Opposite Direction

Table I shows the output in volts and amperes of the early Ford magneto at various speeds.

Timer. The timer is used to distribute the primary ignition current to the proper coil at the time a spark is desired to explode a gas charge in a cylinder.

By referring to Fig. 69, it will be noted that there are four contacts around the inner part of the timer equidistantly spaced.

A roller is mounted on the front end of the camshaft which makes contact with these segments, thereby completing the primary circuit through the spark coil, causing the vibrator to operate, and producing a secondary spark at the spark plug. A diagram of the ignition circuit is shown in Fig. 70. The coil box on all Ford cars is provided with a battery terminal so that a battery can be utilized for ignition purposes if desired. On the cars equipped with a starting system at the factory, the starting battery is connected to this terminal. The Ford Motor Company recommends that the car be started with the ignition switch in the battery position and run on the battery until the engine warms up. The magneto should then be used for ignition as it

Fig. 69. Ford Timer

is designed to meet this service. The battery connection is made through the lighting and ignition switch.

Path of Ignition Current. By referring to Fig. 70, it will be seen that when the switch is on **BATTERY,** the current leaves the positive pole of the battery, passes to the starter switch, to the second terminal on the terminal block, and through the ammeter to the battery terminal on the back of the switch. The current then travels to the busbar in the bottom of the coil box, through the primary winding of coil No. 1—the timer contact is on segment No. 1—through the vibrator points to terminal No. 1 on the timer, to the timer roller, and to the ground, and returns to the negative post of the battery. As the current flows through

the primary winding of the coil, the vibrator starts to operate and a current of high voltage is induced in the secondary winding every time the vibrator points open. This high-tension current flows to the spark plugs and returns to the other end of the secondary winding through the timer and the timer wires.

Fig. 70. Ignition Wiring Diagram

When the switch is turned to **MAG,** the current is taken from the terminal of the magneto and flows to the first terminal of the terminal block, to the magneto terminal on the back of the switch, and across the switch and to the busbar in the coil box. The remainder of the magneto circuit is the same as the battery circuit except that the magneto current returns to the grounded end of the magneto coils instead of to the battery.

Testing Dash Coils. If it is thought that the ignition coils are out of adjustment when the motor misses or is hard to start, they can be easily tested from the front seat. The cylinders that are missing can also be located by this method.

Remove the coil-box cover and speed up the motor to a car speed of about 12 m.p.h. Then press down on vibrators Nos. 1 and 2 and note the action of the motor. If two explosions are distinctly heard at the exhaust, it is a sign that Nos. 3 and 4 are operating all right. If, however, there is just one explosion, it is a sign that one of these cylinders is not working properly. This fault can be located by the process of elimination. Release No. 1 vibrator and hold down No. 3 instead; if only one cylinder is then firing, it is a sign that either No. 4 or No. 1 is defective. Either one can be eliminated by holding down its vibrator. If the motor stops, it should be tried again with the throttle open a little more. If vibrator No. 4 is then depressed and the motor stops firing, it is a sure sign that No. 1 cylinder is missing; this, however, may not be coil trouble. To eliminate any possibility of coil trouble, one of the properly working coils should be lifted out and exchanged with the supposedly defective coil. If the cylinder still misses, the spark plug should be examined; if the spark plug is all right, the motor should be examined for loss of compression, valve trouble, dirty commutators, loose connections, or broken wires.

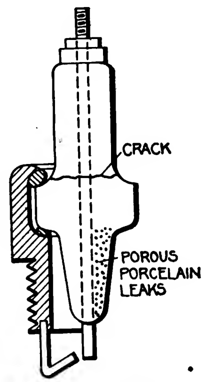


Fig. 71. Damaged Spark Plug

Spark Plugs. In Fig. 71 is shown a partial section of a spark plug. The center electrode is made of heat-resisting metal so that it will not fuse and melt away. The porcelain or electrode insulator is made of material that will not crack with either heat or cold. It must also withstand any sudden change in temperature without cracking. If the porcelain does crack or become porous, as in Fig. 71, it is useless to try to use it as the spark will pass through the pores instead of jumping the gap at the points. The current always takes the path of least resistance and the resistance of a spark gap under pressure is much greater than that of the path through the porous porcelain.

Care of Ignition System. The timer should be removed at regular intervals and inspected. Any old grease containing a great deal of grit and cuttings should be carefully removed. The contacts should be inspected to make sure that there are no uneven or worn places such as shown in Fig. 72. If the timer is in this condition, the motor is likely to miss when running at a fair rate of speed. The timer roller will enter the low places and bounce over the contact. The roller spring should be carefully examined as the end of this spring may be worn almost in two, and if it is replaced in this condition, it is sure to cause trouble.

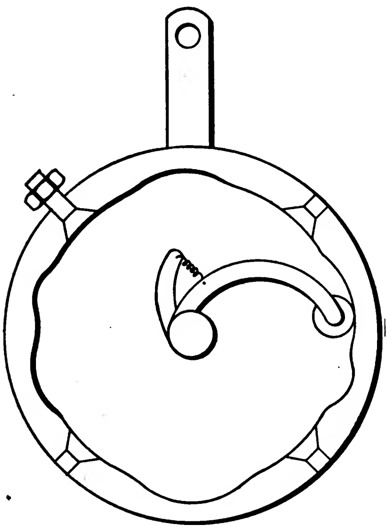


Fig. 72. Worn Timer

Timer Wires. The timer wires are enclosed in a loom to prevent them from being damaged mechanically and to keep them free from oil. They should be carefully examined to see that there are no bare wires exposed, especially where they connect to the timer. If there is an accidental ground in these wires, the motor will miss, backfire, or "kick" when it is cranked.

STARTING AND GENERATING SYSTEM

GENERATORS

Function. The generator produces an electric current that replaces current used from the storage battery. When the starter is used, current is discharged from the storage battery, and this current must be replaced as the battery would be exhausted if this were not done. The lights also take current from the battery when they are in use if the generator is not generating sufficient current to supply them. Fig. 73 shows the assembly of the starter drive and an outside view of the generator.

It has been stated that if an electric current is passed through a conductor, which may be in the form of a coil, a magnetic field

Armature Shaft

Generator Driving Pinion

GENERATOR

Fig. 73. Starter and Generator Units

is produced about the conductor. The introduction of an iron bar in the coil greatly increases the magnetic effect because it is much easier for the magnetism to travel through the iron than through the air inside the coil of wire. For this reason, the iron core is always used in the electromagnet.

It is also true that if a conductor is passed between the poles of a magnet through the magnetic field, an electric pressure is generated, or induced, in the conductor which will cause current to flow. The greater the number of magnetic lines of force cut per second by this conductor, the greater will be the amount of current flowing through it. These magnetic lines of force can be increased by winding the field coils with a greater number of ampere turns; by using a higher voltage on the fields; or by increasing the speed of the generator.

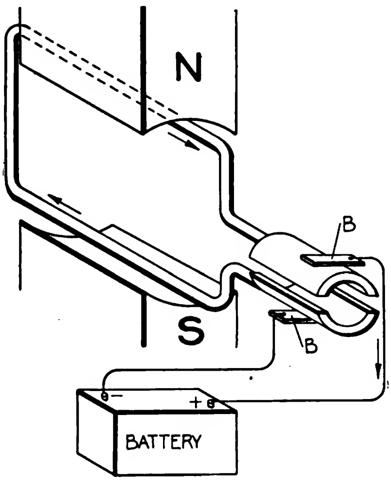


Fig. 74. Simple Generator

Fig. 75. Windings of Modern Armature

A simple generator is shown in Fig. 74, in which a loop of wire is revolving between the poles of a magnet. In order to carry the current that is induced in the loop of wire into the external circuit, a commutator is provided. This consists of two segments, each being connected to an end of the wire loop. Two brushes *B* run on this commutator to collect the current. In all modern generators a number of loops or coils of wire are mounted in a rigid manner on a laminated iron core, forming the armature, Fig. 75. The brushes are so placed on the commutator that the

current collected by them flows from one brush through the external circuit and back to the other brush.

Regulation. Since the voltage generated in the armature of a generator is proportional to the number of magnetic lines cut per second, it is evident that by regulating the speed at which the armature travels, we can regulate the voltage generated. It is also evident that by regulating the field strength, and thus changing the magnetic lines flowing through the armature, we can regulate the voltage generated. The latter method is used in the Ford generator. If this voltage were not held within certain limits, the lights on the car would be burned out as the high voltage would force enough current through the lamp filaments to melt them and cause an open circuit.

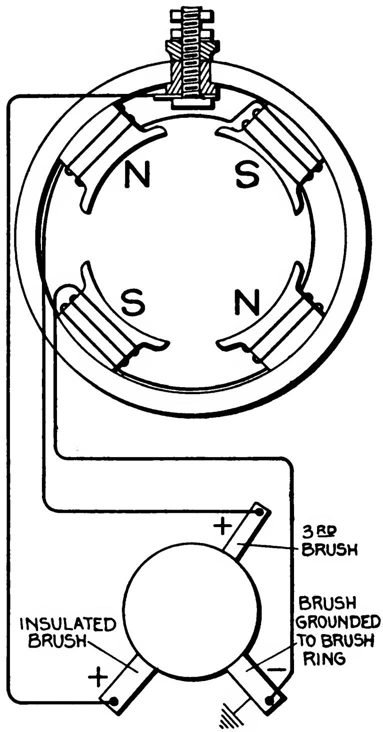


Fig. 76. Generator Field Connections

Third Brush. The Ford generator decreases the field strength by the use of the third brush. The field winding is connected between the grounded main brush and the small third brush which bears on the upper side of the commutator, Fig. 76. The position of this brush may be changed so that it is nearer to or farther from the grounded main brush. The distance between these two brushes determines the maximum strength of the current delivered at the generator.

The action of the third brush is as follows: When the generator is operating at a low rate of speed, the magnetic lines of force pass in a straight line from the north field pole to the south field pole, Fig. 77. It will be noted that the third brush is bearing on the commutator segments that are in the direct path of these magnetic lines of force. When the speed of the generator is

increased these magnetic lines are distorted, Fig. 78. This causes the coils that are connected to the commutator bars on which the third brush bears to be out of the direct path of the magnetic lines. The voltage generated at the bar on which this third brush bears will then be decreased, and as decreasing the strength of the field coils decreases the total number of magnetic lines cut by the armature, the output of the generator will be reduced.

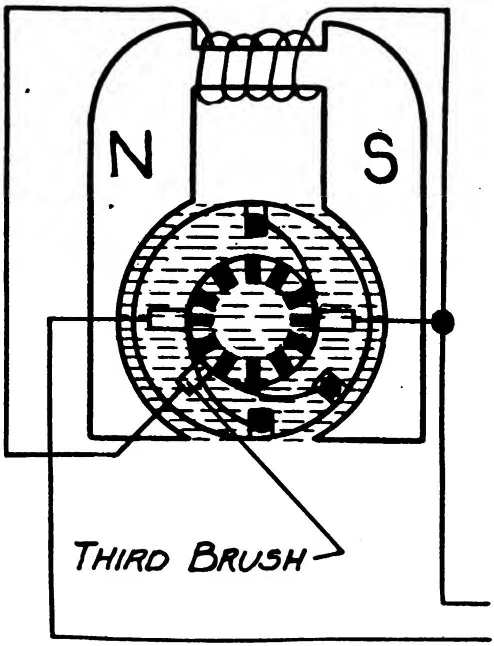


Fig. 77. Path of Lines of Force

To regulate the output of the Ford generator, all lights should be turned off and the motor should be run on the magneto. The generator should be warm when the change is made. Remove the cover that closes the opening in the rear end of the generator housing. This is done by taking out two round-headed screws that hold this cover in place. The hexagonal nut holding in place the bolt that clamps the third-brush holder to the brush ring is reached through the opening in the rear-end housing. It is at the right of the generator terminal when facing the rear end of the generator. A small, thin, open-end wrench is the best

one to use in turning this nut. Loosen it and then tap the third-brush holder so as to move it in the slot in the desired direction. Moving the third brush in the same direction as the armature is rotating increases the charging rate; moving it in the opposite direction decreases the charging rate, Fig. 79. The engine should be running at about 800 r.p.m. and when the desired output is obtained, the nut should be tightened. The engine should then be run at different speeds to make sure that

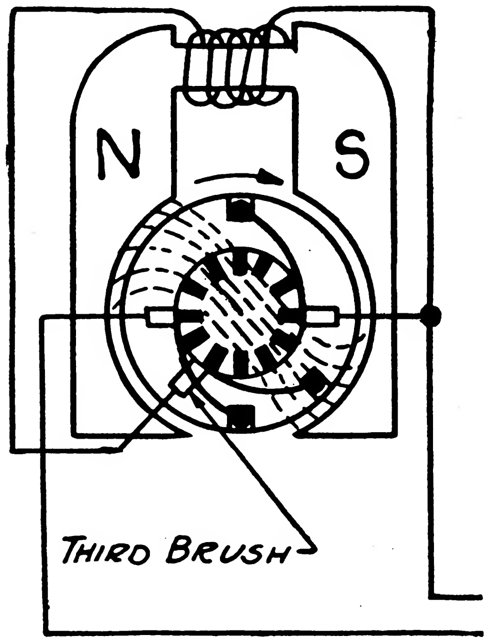


Fig. 78. Distorted Lines of Force

the current does not reach a value greater than that indicated before the nut was tightened. The brush should be set so that the highest reading is between 10 and 12 amperes. It is good practice to *sand-in* the third brush after it has been set in its new position until all points of the brush touch the commutator. The method of sanding-in the brush is shown in Fig. 80.

Shunt-Wound Generator. The Ford generator is shunt wound, which is to say, only a portion of the current generated passes through the field coils, or the shunt, of the generator. The

connections of the shunt fields are shown in Fig. 76. On each of the four field poles is wound a single field coil, and these coils are connected in series with each other. The joints between the coils are made by soldering the wires together and covering the joint with tape. The resistance of the four field coils when cold is about 2.45 ohms.

Proper Generator Operation. The cutout should close when the generator is running at about 600 r.p.m., or at a car speed of 10 m.p.h. At this speed the voltage of the generator should be a little higher than that of the battery so that the generator can charge the battery just as soon as the points close. As the speed of the engine increases, the output of the generator will continue to increase until the generator is running at 1200 r.p.m. or a car speed of 20 m.p.h. At this speed the current reaches its maximum value; at higher speeds the charging rate decreases. This decrease is caused by the almost complete distortion of the magnetic lines of force, which distortion decreases the voltage at the third brush.

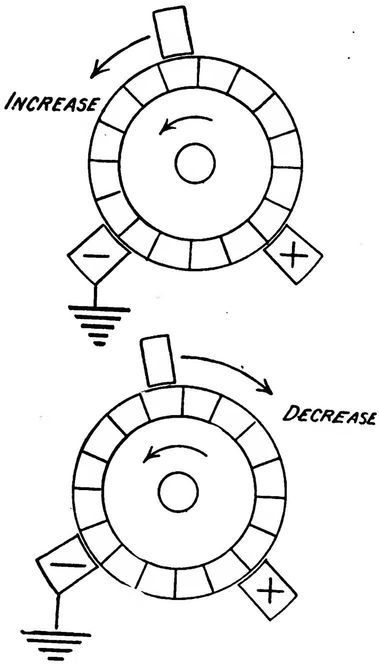


Fig. 79. Regulation of Third Brush

A charging rate of 10 amperes is the best for average driving conditions. The cutout will not open and disconnect the generator from the battery until the voltage of the generator has dropped slightly below that of the battery, when the battery will begin to discharge into the generator. This will be indicated by the pointer of the ammeter coming to the O line and moving on the discharge position to 1 or 2 amperes. This discharge current should not exceed a few amperes and should flow for only an instant before the cutout points open.

Cutout. The purpose of the cutout is to automatically connect the battery to the generator when the voltage of the gen-

erator is greater than that of the battery, and to disconnect the battery from the generator when the voltage of the battery is greater than that of the generator. This action is necessary to prevent the battery from discharging into the generator when the motor is not running.

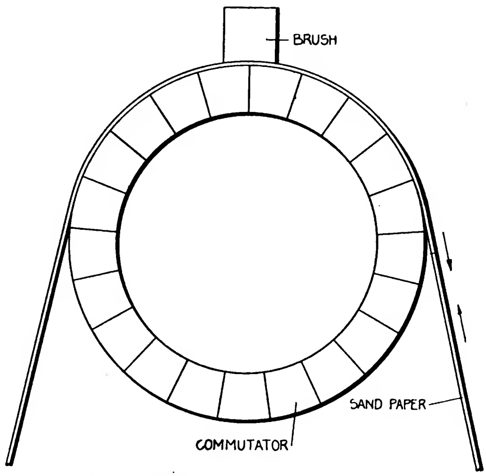


Fig. 80. Method of Sanding-In a Brush

To accomplish this automatic action, two windings are placed on the cutout core, Fig. 81. One is of heavy wire and carries all the current generated by the generator, and the other is of small wire connected so that it will receive the full voltage of the generator. The small wire, or voltage coil, performs the duty of closing the contact points when the generator voltage is slightly greater than that of the battery. The small amount of current generated at low speeds flows through this fine winding and magnetizes the core so that it is strong enough to overcome the tension of the spring that holds the points apart. The points then close, and as long as the generator is charging the battery, the points remain in this position. The charging current flows through the heavy winding and holds the points together. When the voltage of the generator falls below that of the battery, the current begins to discharge into the generator, and therefore the current through the heavy winding is reversed. Before the reverse

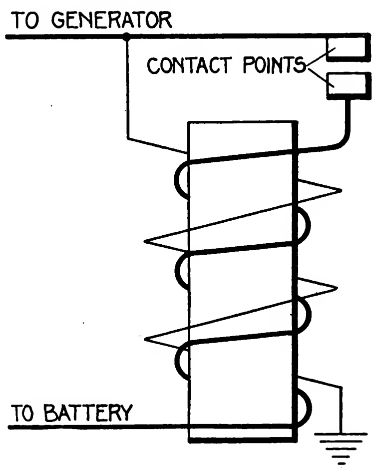


Fig. 81. Simple Cutout

current starts to flow, the core loses its magnetism as no current is flowing in either direction. The spring will then open the contact points, breaking the circuit between the battery and the generator and preventing the battery from discharging into the generator.

Cutout Mounting. On many cars, the cutout is mounted under the engine hood on the right side of the dash, and the base

Fig. 82. Cutout Mounted on Dash

of the cutout is grounded to an iron arm projecting upward from the frame of the car. On later cars, the cutout is on top of the generator, and its frame is grounded directly to the generator.

Cutout on Dash. There are three terminals on the base of the cutout, Fig. 82. The two outside terminals are marked BATT and GEN; the one marked BATT is connected to the

ammeter, and the one marked **GEN** is connected to the generator terminal. The two outside terminals are insulated from the base of the cutout, while the middle one, which is not marked, is grounded to the base. A movable arm carries one of the contacts, and a flat spring tends to hold the two contact points apart. Passing through an opening on this arm is a brass arm stop, and by bending or straightening this piece, the distance between the two contact points may be changed. The correct distance is about $\frac{1}{32}$ inch.

The stationary contact point is carried on an arm that is insulated from the upright piece to which it is mounted. The distance between the points may also be changed by moving this arm up or down.

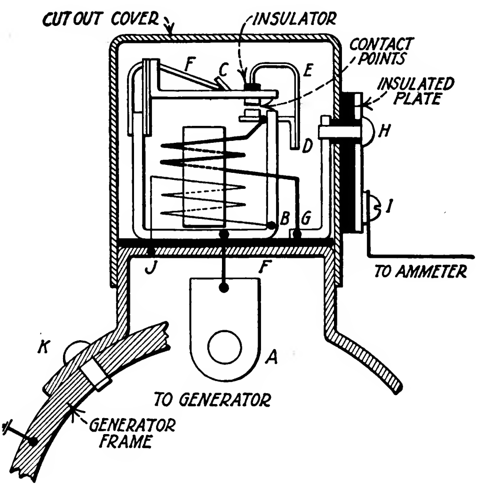


Fig. 83. Cutout Mounted on Generator

Cutout on Generator. The internal connections of the cutout when mounted directly on top of the generator are shown in Fig. 83. The part A is bolted to the generator terminal and is connected to B by a round-headed machine screw which may be seen by looking at the bottom of the cutout; A and B are both insulated from the base of the cutout, which is fastened to the base of the generator. The arm C is mounted on and electrically connected with B, and at one end of the arm C is one of the contact points. The other contact point is fastened to D, which is insulated from B and C. A brass hook E, which is an extension of D, acts as a stop for the arm C. This hook can be bent, when the motor is not running, to change the air gap between the points so as to secure proper operation of the cutout when the generator is running. The spring F tends to hold the contact points away from each other; and the tension of this spring may be increased or decreased by bending it to secure proper action of

the cutout both in opening and in closing the circuit between the generator and the battery.

Voltage-Coil Circuit. The circuit through the voltage coil is as follows: from the ungrounded main brush to the generator terminal, through *A* to *B*, through the voltage coil to the base *J*, through the generator frame, thence to the grounded main generator brush, and back to the armature.

Current Through Cutout. Current from the generator enters the cutout at *A* and travels into *B* and *C*, through the contact points into *D*, thence through the outside winding, which is heavy wire, and into *G* which is insulated from all parts except the coil. The current then passes through the screw *H* into the insulated plate. This screw passes through the cutout cover but is insulated from it. The current then goes to the battery along the wire fastened to this plate under the screw *I*. The screw *H* is sealed to the cover and should always be turned down tight as the charging circuit is broken if this screw is removed.

The base of the cutout, which is screwed down to the generator frame, is connected to one end of the voltage coil but is insulated from all other parts except the cover which fits over it; the other end of the voltage coil is connected to *B*.

Care of Cutout. The contact points should at all times be clean and smooth, and when they are touching each other they should make contact at all points of their surfaces. They may be cleaned by drawing a rag moistened with gasoline between them; to make them smooth, a piece of fine sandpaper or a fine file may be used, drawing the emery cloth or the file between the contacts while the movable contact is pressed down.

The movable arm which carries one of the points is insulated from the base of the cutout; care must be taken to see that it does not become grounded to the base.

Adjusting Cutout. To adjust the cutout, be sure that the generator is generating about 10 amperes. The specific gravity of each of the battery cells should not be less than 1.250. Turn off all the lamps and run the motor on the magneto. With the motor running slowly, close the throttle until the points open. The points may be watched to see when they separate, or the ammeter pointer may be observed. The pointer will swing past

the O on the ammeter just before the points open, and will then come back to the O line and remain in that position. Now gradually increase the speed of the engine, carefully watching the ammeter. When the motor is running at 600 r.p.m., or at a car speed of 10 m.p.h., the cutout points should close. There should be a slight movement of the ammeter pointer when the cutout closes, indicating a charge of 2 or 3 amperes. With a further increase in speed, the ammeter pointer should gradually go to 10 amperes, and this should be the maximum charging rate.

When the cutout closes and the ammeter reads reversed, thus indicating that the battery starts to discharge into the generator, the cutout is closing before the voltage of the generator is equal to or greater than that of the battery. This is remedied by bending the spring on the movable arm of the cutout so that the spring will hold up this arm with greater force. It will then require a higher generator voltage to close the cutout circuit. Another way is to increase the distance between the points by straightening the hook, or the bent-over piece, a little.

If the ammeter pointer does not move when the cutout points close, it indicates that the generator and the battery voltage are equal at this instant. The spring on the movable arm should then be made stronger by bending, or the distance between the points should be increased.

If the ammeter indicates 10 amperes charge when the points close, the cutout does not close soon enough. To remedy this, the spring on the arm should be weakened, or the distance between the points decreased.

Checking Cutout Action. To check the action of the cutout in disconnecting the generator from the battery, gradually decrease the speed of the generator and watch the ammeter pointer. The pointer should not move past the O line more than 2 or 3 amperes. Should this pointer indicate a discharge of more than 3 amperes or should it remain below the O line for more than an instant, then the points are not opening soon enough, and the spring on the movable arm should be straightened, or weakened.

Removing Generator. When it is necessary to take out the generator, the three cap screws that fasten to the front end of the cylinder block should be removed. Then place the point of

a screw driver between the generator and the front end cover and gradually force out the generator. Always start prying at the top of the generator and force it backward and downward at the same time. If it is desired to run the car while the generator is removed, the timing-gear-case opening where the generator was removed should be covered with a plate. This plate can be secured from any Ford dealer or service station.

Remove the cover that closes up the opening in the rear-end housing by taking out two screws *B* that hold it in place, Fig. 84.

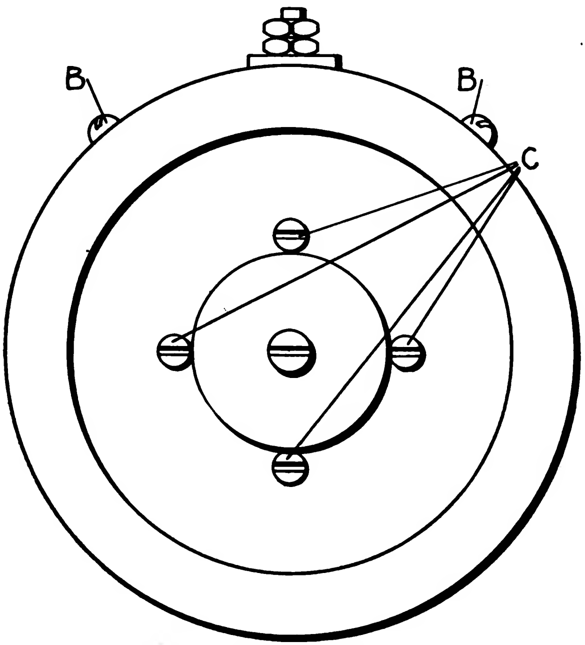


Fig. 84. Rear End View of Generator

Grasp the pigtails on each brush with a pair of long-nosed pliers and pull the brushes up until the brush springs snap from the top of the brushes and bear against their sides. This will hold the brush clear of the commutator. Then take out the six flat-headed screws, *A*, Fig. 85, and insert the point of a screw driver between the front-end cap and the frame and pry the cap loose. Next take hold of the generator and pull out the armature. Remove the rear-end housing by taking out the four screws *C*, Fig. 84, and pry the housing loose with a screw driver. When do this, be

careful not to damage the insulation around the generator terminal. When the rear-end housing is loose, it may be pulled back as far as the wires fastened to the brushes will allow. These wires should then be disconnected, or they may be disconnected first, care being taken to note the connections so that they may be correctly replaced. Fig. 76 shows the proper connections.

To remove the brush ring, take out the four screws shown at *C* in Fig. 84. The main brush-holders are riveted to the ring

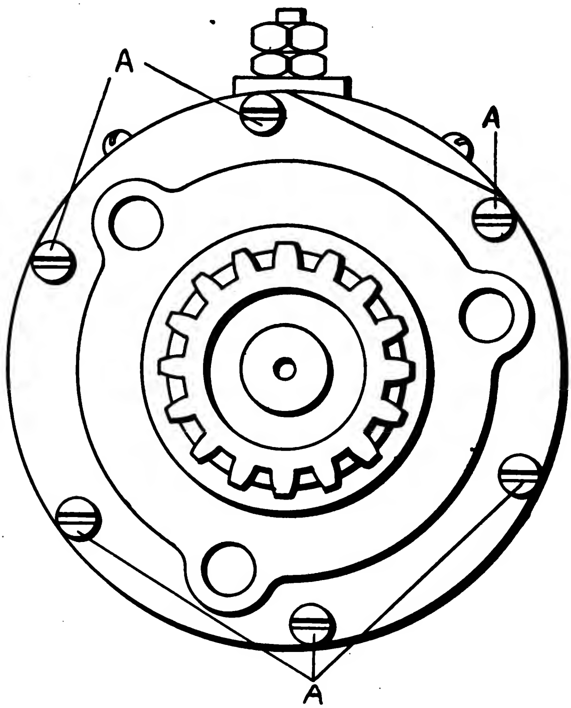


Fig. 85. Front End View of Generator

and cannot be removed from it, while the third brush-holder is removable.

Armature. The generator armature is shown in Fig. 86. It has twenty-one slots and twenty-one segments on the commutator, and the wires are enameled and cotton covered. The only part of the commutator that requires attention is that on which the brushes bear, and this should be kept clean and smooth and free from oil. There will be no trouble caused by a greasy com-

mutator, if the rear-end bearing on the generator is not given too much oil and the oil-retaining washer at the front end of the generator is in good condition. To clean a greasy commutator hold first a dry rag against it, then a rag moistened with kerosene when the generator is running. Do not use too much kerosene on the rag and always run the generator for a few minutes after the rag is removed so that any surplus kerosene may be dried up. The space between the commutator segments should be kept free from oil, grease, bits of carbon, and copper. These spaces may be cleaned with a sharp-pointed tool, scraping out the dirt until the clean mica shows the entire length of the commutator. The mica should be cut down until it is about $\frac{1}{32}$ inch below the surface of the commutator. If the commutator is

Fig. 86. Generator Armature

rough, it may be smoothed by holding a piece of fine sandpaper against it. *Never use emery cloth!* If there are grooves around the commutator, it should be turned in the lathe until the surface is smooth and of the same diameter at all points.

Wiring Diagrams. A wiring diagram of the complete electrical system of the Ford is shown in Fig. 87. This system is for all cars having the cutout mounted on the dash. A diagram for all cars having the cutout mounted on the generator is shown in Fig. 88.

Generator Troubles. *Generator Reversed.* To test the generator for reversal, a voltmeter should be used, Fig. 89. Hold one test point on the ground on any clean metallic spot of the generator frame and the other test point on the generator terminal. The voltmeter should show a voltage of about 7 to $7\frac{1}{2}$. If the needle moves backward the polarity of the generator is reversed.

Fig. 87. Wiring Diagram with Cutout on Dash

Fig. 88. Wiring Diagram with Cutout on Generator

This generally happens when the battery is run down. To remedy this trouble, put in a fully charged battery and hold the cut-out points closed, by hand, for an instant. Then look at the ammeter to see if the generator is charging the battery. If the battery is still discharging, reverse the field connections in the generator.

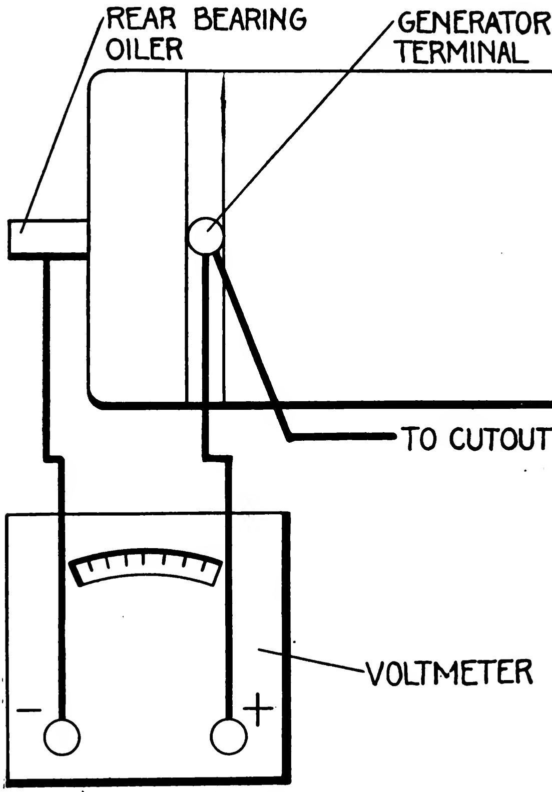


Fig. 89. Testing Generator for Reversal

To do this, the field wires that are connected to the third brush and the grounded main brush are exchanged.

Shorts and Grounds. The generator field takes about 2.5 amperes when it is connected to a 6-volt battery if the fields are not shorted or grounded. When the generator runs as a motor, it takes 9 amperes from a 6-volt battery if there are no shorts or grounds in the armature or fields. If there is an indication of a short or a ground, remove the housing cover and inspect the

wire leading from the terminal on the generator to the ungrounded main brush and the wires leading from the field coils to the third brush and the grounded main brush. The insulation on these wires should not be cut or torn, and the pigtails should not touch the end housing or the brush ring, although no damage will be done if they touch the brush-holders.

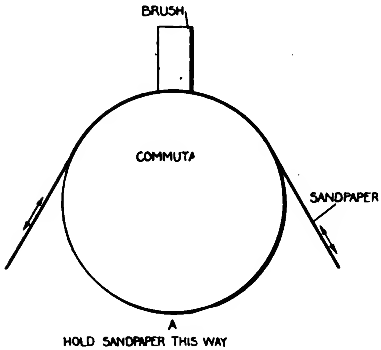


Fig. 90. Correct Way to Sand-In Brushes

Sparking at Brushes. Excessive sparking at the brushes should be prevented. If the brushes are of poor material or are the wrong size or type of brush, they are likely to spark. A spark will also take place if the brushes are not set in proper relation to the windings. If the armature is loose or the commutator is not running true on the armature shaft, sparks will also develop at the brushes. If some of the armature coils are short, or open-circuited, the sparking will occur only when the commutator segments to which the coils are connected pass under the brushes. If two adjacent segments are blackened or burned, it is plain that there is a short-circuit present between the windings connected to these segments.

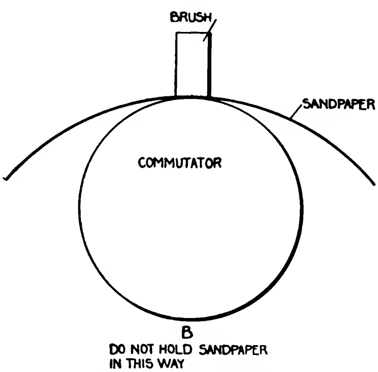


Fig. 91. Incorrect Way to Sand-In Brushes

Brush Trouble. For inspection the brushes may be removed by the use of long-nosed pliers; pulling on the brush pigtails removes the brushes from their slots. Of course, the dust cover must be removed in order to get at the brushes. After they are removed, they should be examined for dirty, pitted, or insufficient contact surface. The parts of the brush surface that make contact with the commutator will be smooth and polished, while the other parts will be dull and rather rough. If the brush contact surface is not perfect, cut a piece of fine sandpaper and insert it between the brush and the commutator with the sanded side

toward the brush, as in *A*, Fig. 90. In Fig. 91, *B* shows the incorrect way of sanding-in the brush. The sandpaper should be drawn back and forth under the brush until all imperfections in the brush surface have been removed when the brush will fit the curvature of the commutator properly. When the brushes are too short, they will give unsatisfactory service, as the spring tension is greatly reduced. Brushes in these conditions should be replaced by brushes secured from the manufacturer of that particular instrument. As a rule, it is not good policy to use any brushes other than those manufactured by a reliable concern and for that particular instrument only.

Improper Spring Tension. If the brush springs are broken, total failure of the instrument may result, or if the brush-holder becomes gummy so that the brush sticks, a great deal of sparking at the brushes will be present. Sparking is sometimes the result of loose brush springs also.

Defective Insulation. If the insulating washers are broken or in any way damaged, they should be replaced with new ones. Any grease or any gummy substance should be removed from the brushes and the brush-holders cleaned with a stiff hairbrush and gasoline.

TESTING

Testing Armature and Commutator. A single dry cell is best to use in testing the armature windings for opens or shorts. The cell should be connected in series with an ammeter, Fig. 92. One post of the cell is connected to one terminal of the ammeter and a wire having a testing point at one end is connected to the other post. If desired, this testing point may be eliminated and the bare wire used instead. A wire is connected on the other terminal of the ammeter and the free ends of the two wires are used to make contact on the various segments of the commutator, Fig. 93. Before making the test, the brushes may be raised from the commutator, or, better still, the armature may be removed from the generator where it will be much more accessible. The test should be started on any point of the armature, the two leads touching the two adjoining segments. Note the reading on the ammeter and then proceed to the next segments.

For example, the wire should be placed on segments Nos. 1 and 2 and then on Nos. 2 and 3, etc. The readings of all segments should be compared, as any great difference is indicative of trouble on those coils which have different readings. It must be remembered that when the wires are on contact, a circuit is completed through the armature, the ammeter, and the dry cell which will fully discharge the cell if contact is held for any length of time; just enough contact to allow the operator to read the ammeter should be made.

If the commutator and the armature are free from short or

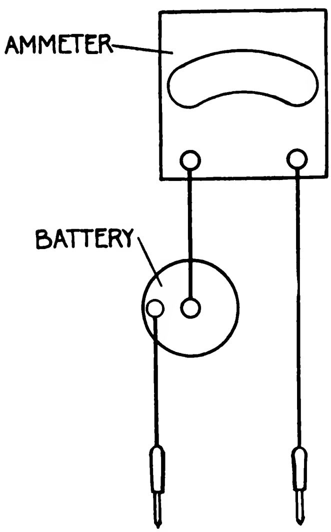


Fig. 92. Armature Testing Set

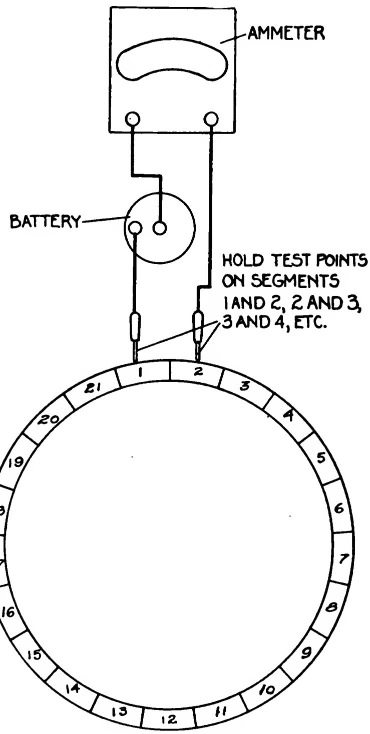


Fig. 93. Testing Armature Coils

open circuits, the ammeter readings between the various pairs of segments will be about equal. In case the reading becomes much higher with the test points resting on any pair of segments, this condition indicates that either the armature coil attached to these segments or the segments themselves are short-circuited. If the reading becomes much less, this indicates that a broken, burnt-out, or otherwise open-circuited armature coil is present between the two segments where the test points are then touching.

Open Circuit. If an open circuit exists, make sure that the wires soldered to the segments are making perfect contact and that they are not broken as far as they can be traced. If no trouble can be detected on the surface, it will then be necessary for the armature coil to be unwound until the trouble is found, when repairs can then be made and the armature rewound.

Short-Circuit. If the test indicates that a short-circuit is present, the mica slots should first be thoroughly cleaned, removing any bits of metal or carbon that may have lodged in them. If any of the commutator bars have been damaged so that the

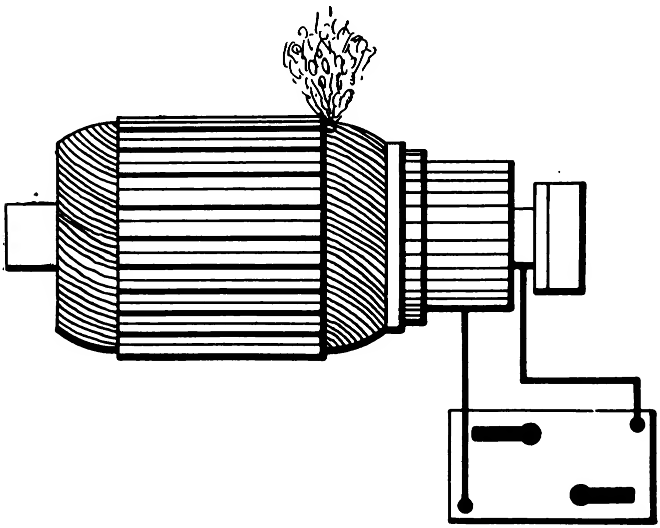


Fig. 94. Locating a Short in the Armature

copper touches another bar, the metal should be cut away until they do not touch. If this does not eliminate the trouble as shown by a record test, the short-circuit is in the armature winding. This short-circuit can generally be located by using a 6- or a 12-volt battery, connecting No. 0 leads to the battery terminals and touching the other ends of these wires to the segments that indicate a short, Fig. 94. In the majority of cases, smoke will be produced at some point on the armature, thus showing where the short exists, and it can often be repaired without removing the winding. It is sometimes possible to burn out this short with a

6-volt battery, although some manner of insulation such as shellac or tape should be made after this kind of repair has been made.

Testing Fields. *Open Circuit.* In making this test, all brushes should be insulated from the commutator by inserting a piece of paper between each brush and the commutator bars. A 6-volt battery should be used to make the test, having a 6-volt bulb in series, Fig. 95. Disconnect the wire from the main brush-holder and touch this wire with one test point while the other test point is placed on the third brush. The lamp should light; if it

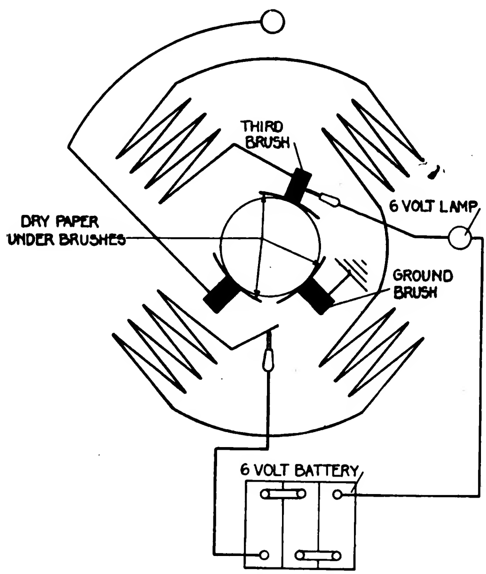


Fig. 95. Testing Field for Open Circuit

does not, this is a certain indication of an open in the shunt winding. The joints between the field coils should then be carefully inspected as the soldering sometimes becomes loosened, causing a poor connection or an open circuit. If the solder on these connections proves to be firm, each coil should be tested by placing the test points on the soldered connections between coils Nos. 1 and 2 and Nos. 3 and 4, etc., Fig. 96. If the lamp does not burn when any coil is tested in this manner, the coil is open-circuited. In order to repair the open, it will be necessary to remove the coil. To do this, take out the screw that holds the

pole piece in place and disconnect the coil from the adjoining coil. If the broken circuit is not visible, the coil must be carefully unwound until the break is located. It will then be necessary to make suitable repairs, taking special care to see that each coil is properly insulated.

Ground. To make tests for a ground in the fields, the tester should be used according to the method shown in Fig. 97. With the brushes still insulated from the commutator, one test point should be placed on the third brush and the other point on any

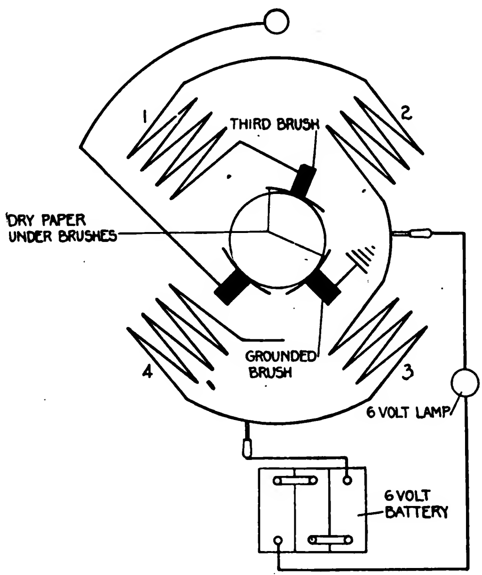


Fig. 96. Testing Each Coil for Open Circuit

part of the generator frame. If the lamp lights, there is a ground in the field coil or the third brush-holder. If the lamp does not light, hold the test point that was on the generator frame on the end housing, this part being removed and not touching the generator. If the lamp now lights, the third brush-holder or the insulated brush-holder mounted on the brush ring in the end housing is shorted. The brush ring must then be removed and the insulation under the brush-holders carefully inspected to locate the ground. If the lamp lights when one test point is held on the third brush and the other test point on the generator

frame, there is a ground in the field coils. Connection between the field coils should be carefully inspected for damaged insulation or places where the bare wires are touching the frame. If these connections are in good condition, it will be necessary to disconnect the field coils from each other by unsoldering the joints between them. Each coil should then be tested separately by holding one test point on the generator frame and the other point on a coil terminal. When the lamp lights, the grounded coil has been located. The coil should then be removed as previously

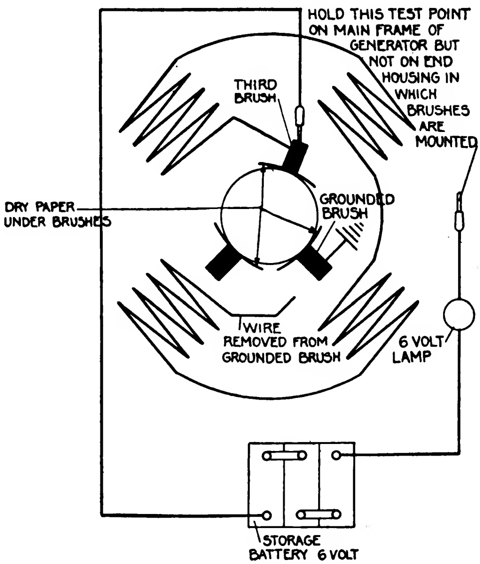


Fig. 97. Testing for Grounds in Fields

described and the ground repaired. The ground in a field coil is much easier to locate than a short, as the ground will generally be present at a point where it touches the field cores, and then it is usually only necessary to retape the coils. This test is shown in Fig. 97.

Short-Circuit. In order to test the coils for a short-circuit in their windings, the tester should be used as shown in Fig. 98. Note the amount of current flowing through the ammeter when the coil is being tested. With a 6-volt battery, a current of about 10 amperes should flow. If any coil takes more than 10 amperes, it

indicates that this coil is shorted, and it should be removed and inspected. The field should be repaired, if possible, and carefully reinsulated before replacing.

Reversed Fields. To test the polarity of the fields it will be necessary to use a small compass as in the method shown in Fig. 99. Alternate fields should show opposite polarity. The compass should be held about 1 foot from the generator frame and gradually moved toward one of the screws that hold the field

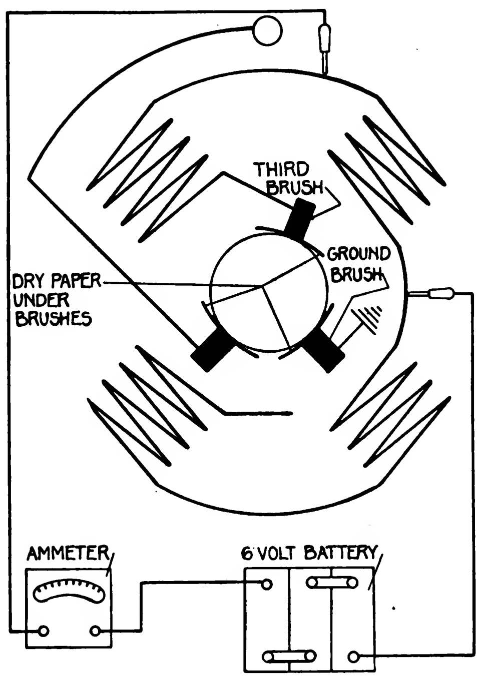


Fig. 98. Testing Coils for Short-Circuit in Fields

poles in place. The compass should then be moved toward another screw and brought nearer, when it should indicate the opposite polarity. If three successive poles attract the same end of the compass needle, the coil on the middle pole is wrongly connected, and its connections should be reversed for proper operation.

Generator Terminal Grounded. Sometimes the insulation around the generator terminal becomes cracked and the terminal loosens. If it is left in this condition, a ground sometimes results.

This insulation should be carefully inspected; if it is broken or cracked so that the terminal might touch the frame, new insulation should be put on.

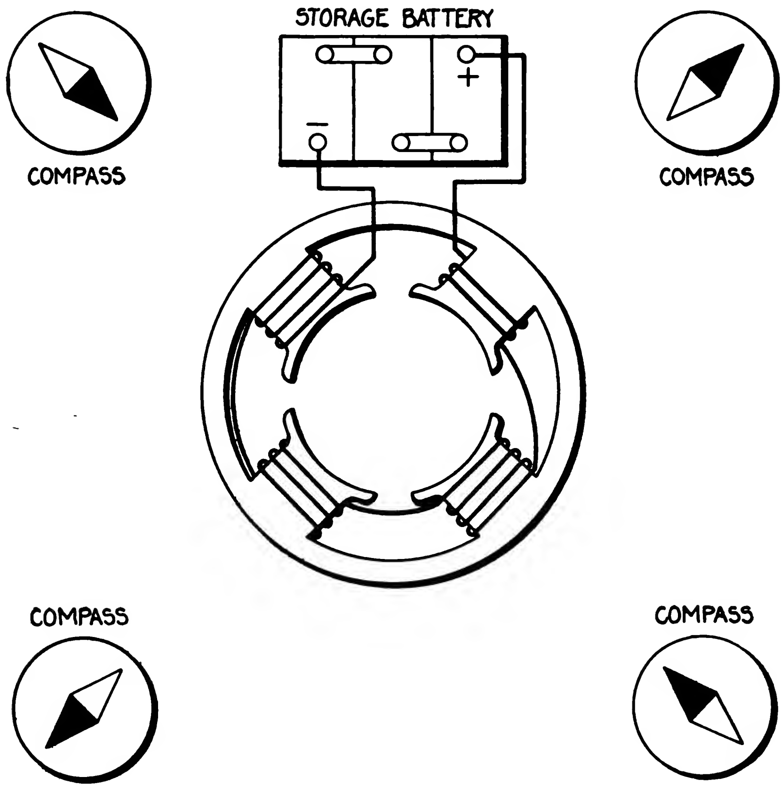


Fig. 99. Testing Coils for Polarity

ELECTRIC STARTER

Construction. The only function of the starting motor is to crank the engine so that it may start under its own power. This motor does not generate any current and is entirely disconnected from the system at all times except when the engine is being started. The starting motor is a four-pole series-wound instrument located on the left side of the engine in front of the flywheel and is fastened to the transmission cover by four $\frac{5}{16}$-inch bolts. The drive is of the Bendix type, which threads the pinion

into mesh with the teeth on the flywheel when the starting circuit is complete by the depression of the starting button. When the engine starts, the flywheel, running at a higher speed than that of the pinion, threads the pinion out of mesh with the flywheel gear, thereby preventing any damage to the starter. The motor pinion has 10 teeth and there are 120 teeth cut on the periphery of the flywheel. The gear ratio is, therefore, 12 to 1, the motor turning 12 times to the engine turning once. The starting armature is mounted on plain bearings, and as the starter is used but little, it is not necessary to supply it with much lubrication. The bearing next to the flywheel is lubricated from the flywheel, while the bearing at the commutator end should not be supplied with any lubricant. The front bushing is made of bronze, the rear is of soft bearing metal, Fig. 113.

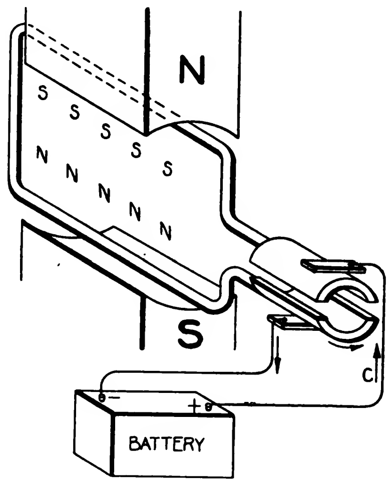


Fig. 100. A Simple Starter

Principle of Operation. The principle of the starting motor is similar to that of the generator, except that the operation of the starting motor is reversed. It has been previously stated that when magnetic lines of force are cut by a coil, a current is induced in this coil; also that an electromagnet has a strength dependent upon the amount of current passed through the coil. It may also be remembered that like poles repel each other and unlike poles attract each other. For instance, a north pole will attract a south pole of another magnet while it will repel a north pole of another magnet. Keeping these facts in mind, let us examine the illustration, Fig. 100. The current flows from the battery into one side of the loop, causing south magnetic lines of force to be set up in the upper part of this loop. The upper motor field, which is a north pole, will then attract the south pole of the coil, and the lower field pole, which has a south polarity, will also attract the north magnetic field that was set up in the lower side of the coil.

TABLE II

Current Consumption of Ford Starter

Condition of Motor	Amperes	Volts	Watts	Horsepower Developed
Running without load	65 to 80	5.75	373	0.5
Cranking new engine at 75 r.p.m.	275 to 300	4.5	1350	1.8
Cranking used engine at 185 r.p.m.	140	5.0	700	0.93

At the same time that this attraction is taking place, there is also a repelling force acting between the upper part of the coil and the south field, and the lower, or north, polarity of the coil and the upper north field. The modern electric motor is composed of a series of loops of wire rigidly mounted and is capable of allowing a large amount of current to flow through its windings. This sets up a strong magnetic pull which produces great turning torque when the starter button is depressed.

Fields. The starting motor is a series-wound machine as shown in Fig. 101. A series winding is used as this type of instrument produces great turning torque at low speeds, which is the result desired from any starting motor. The current consumption of the Ford starter under various conditions is given in Table II.

Brushes. There are four brushes on the starter, one being connected to one end of the series winding and the opposite brush to the other end of the series winding. The two opposite brushes remaining are grounded. The starting current enters the instrument at a connection in the fields shown in Fig. 101. The brushes are of copper composition, and each brush has two heavy, uninsulated, copper pigtails. The free ends of these pigtails are soldered into the copper terminals that are fastened to the brush-holder by a machine screw. The brushes are $\frac{3}{4}'' \times \frac{3}{8}'' \times \frac{3}{4}''$. The brush-holders are made of aluminum and are riveted to the brush ring. The main brushes are insulated from the brush ring by fiber strips, while the grounded brushes are riveted directly to the metal of the brush ring, having no wires except the pigtails. The brush ring is riveted to the housing and therefore cannot be removed. The same care that is given to the brushes and the

commutator of the generator is also applicable to those of the starter.

Removing Starting Motor. In order to remove the starting motor from the car, the pan on the left side of the engine must first be taken off. The four small screws which hold the shaft cover to the transmission cover at the back of the flywheel hous-

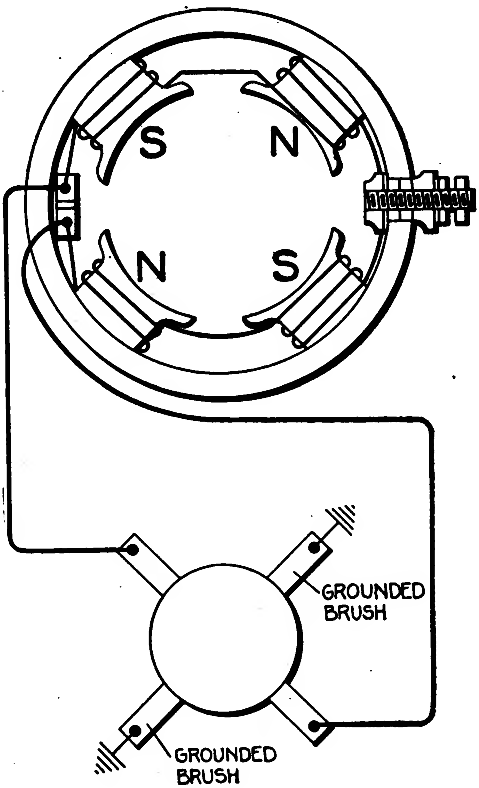


Fig. 101. Series-Winding of Starter

ing should then be removed. Then turn the Bendix drive shaft, Figs. 73 and 113, around so that the set screw on the end of this shaft is in a horizontal position with the head of the set screw pointing toward the left, the operator facing the rear of the flywheel. There is a split spring-lock washer having sharp points at the joint between the two halves on opposite sides of the washer, and

this washer is located under the set screw to prevent it from becoming loose. One of these points is turned against the Bendix collar and the other is turned against the screw head. The point turned up against the screw should be bent back and the set screw removed. The washer is generally broken when removed, so it will be necessary to use a new one when replacing the starter. After the set screw has been taken out, the Bendix pinion spring and sleeve can be slipped off at the end of the starter. The four screws that hold the starter housing to the transmission cover are taken out, and then the motor can be pulled out at the front; lower the motor through the opening in the chassis made by removing the engine pan. If the car is to be used while the starting motor is removed, the hole in the transmission case should be covered with a plate which can be secured at any Ford parts house. When the starting motor is replaced, make sure that the terminal mounted near the rear end of the starter frame is on top.

Dismantling Starter. As the Bendix drive was removed before the starter was taken out of the car, it is now necessary to remove the cover from the rear-end housing. Force this cover off with a screw driver, grasp the pigtails of each brush with a pair of long-nosed pliers, and pull up until the brush spring snaps from the top of the brush and bears against the side of the brush; this action will hold the brush away from the commutator. The six screws in the drive-end cap should be removed and the cap pried off with a screw driver. The armature can then be removed, and it becomes necessary as well to remove the rear-end housing by taking out the four screws that hold it in place. The two leads from the ungrounded brush-holders are next disconnected and the brushes removed by unscrewing the proper pigtails and then lifting the brushes out. The brush-holders, however, cannot be removed. The relative positions of these parts are plainly shown in Fig. 73.

Starter Troubles. The starter may be tested for shorts, grounds, and opens in the same way as the generator. If a test for ground is made and the lamp does not light, the instrument is in satisfactory condition. If the lamp lights, there is a ground in the field. Then the next procedure is to disconnect, one at a time,

the two large insulated field wires from the two insulated brush-holders. Repeat the test as each of these is removed. If the lamp goes out after one of these wires is removed, the brush-holder to which that wire is attached is grounded to the brush ring and must be reinsulated. If the lamp still burns after both wires are removed from the brushes, the ground is in the field coils of the motor. It is then necessary to disconnect each field coil and test it. If the lamp lights when a certain field coil is tested, that field coil is grounded. The coils should be removed and repaired as described on page 113.

Open Circuit. While the field coils are not likely to become open-circuited, still the soldered joints between the coils should be inspected carefully to see that they are well soldered. In making a test for open circuit in the field coils, the connection between any two coils should be opened. The test lamp, Fig. 96, should be used in testing each coil by holding the test points on the bare ends of that coil. If the lamp does not light, the coil is open-circuited and should be removed and repaired as described on page 112.

Bendix-Drive Trouble. Sometimes the starter armature will only spin when the starting button is depressed. This indicates that the spring connecting the pinion sleeve to the armature shaft is broken. This break is sometimes caused by attempting to crank a very cold stiff motor with the starter, or the starter may not be lined up properly. Therefore, it is advisable to loosen up the motor with a hand crank if it is stiff or cold.

Starting Switch. The starting switch is operated by the driver's foot and enables him to complete the circuit between the battery and the starting motor so that the engine may be cranked. A spring in the starter button automatically opens the circuit when the driver's foot is removed, thereby disconnecting the battery from the motor. The switch is located under the floor boards on the left side of the car.

LIGHTING SYSTEM

Bulbs. The headlights contain two bulbs, a 6–8 volt 17 candle-power, and a 6–8 volt 2 candle-power dimmer bulb. The tail lamp has a 6–8 volt 2 candle-power bulb.

It is important to use lamps of the proper voltage as a bulb designed for a lower voltage than 6–8 would be easily burnt out and one with a higher voltage would not give sufficient light.

Bulb Troubles. If the lamps burn out when they are turned on while the engine is running at a car speed of about 20 m.p.h., there is probably a loose connection between the battery and the lighting switch or the generator may be charging at too high a rate; generally the trouble is an open circuit due to some loose or broken connection. If the battery is overcharged, run the starter a few minutes with the ignition switch off or burn the lights over night.

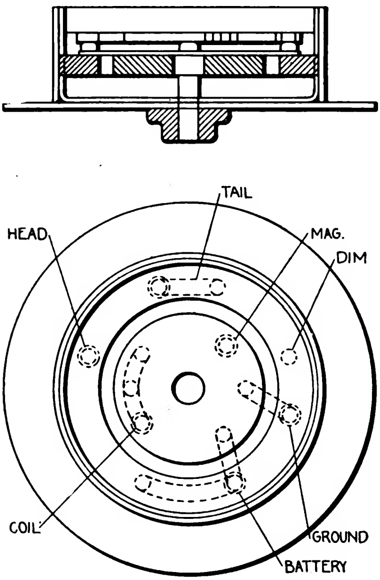


Fig. 102. Early Type of Round Switch

Lighting and Ignition Switches. The Ford sometimes uses a combination lighting and ignition switch, thus enabling the driver to turn the lights on or off and to connect the ignition coils to either the battery or the magneto. This switch is located on the instrument panel in front of the driver. Several types of switches are used. On some of the early models, there is a push-and-pull button for controlling the head lamps, while on the later models, the round-type switch, Fig. 102, is used. On the latest models, the round-type switch shown in Fig. 103 is used. Round-type switches have a handle extending downward from the center of the switch that controls the lamps. The ignition is switched on or off by turning the key inserted in the keyhole in the center of the switch.

Switch Troubles. Some troubles found in the early type of the round switches were generally due to short circuits between the wires connected at the back of the switch. The connections on the back of both switches are shown in Fig. 104. It sometimes happens that it is impossible to turn off the ignition, and in this

event the engine will continue to run after the switch is turned to the **OFF** position. If the ignition key is then turned to **MAG** position, the battery will discharge into the magneto at a rate of about 20 amperes, while the engine is not running. This indicates that the **COIL** terminal on the back of the switch is shorted with the **BATT** terminal. If when the lamps burn out the ignition key is turned to the **MAG** position with the engine running, the

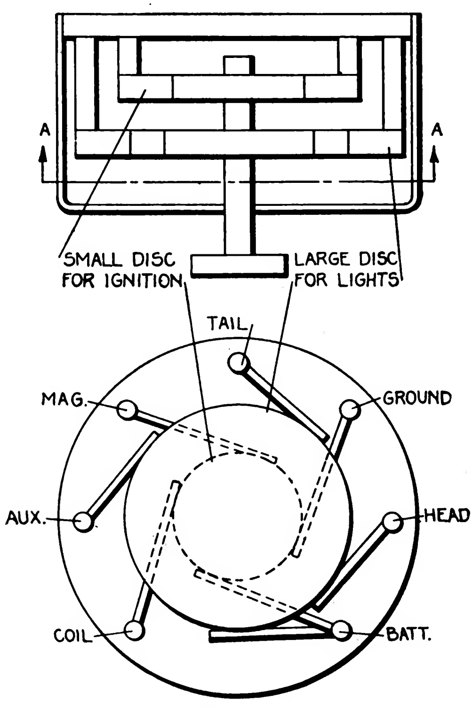


Fig. 103. Late Type of Round Switch

HEAD terminal is short-circuited with the coil terminal. If the battery is used for ignition with this short-circuit present, the head lamps will burn even if the lighting switch is turned off. If the small bulbs in the head lamps burn out, it indicates that the **MAG** terminal is short-circuited with the **DIM** terminal.

With a later type of round switch, these short-circuits do not occur as this switch has two movable round discs, one for the

ignition and one for the lights. When the ignition key is turned to the **BATT** position, the battery furnishes the ignition current. When running and when the generator is charging, this current will be furnished by the generator. When the ignition key is turned to the **MAG** position, the ignition current is furnished by the Ford magneto. When the handle controlling the light switch is turned to the **DIM** or the **AUX** position, the tail lamp and the

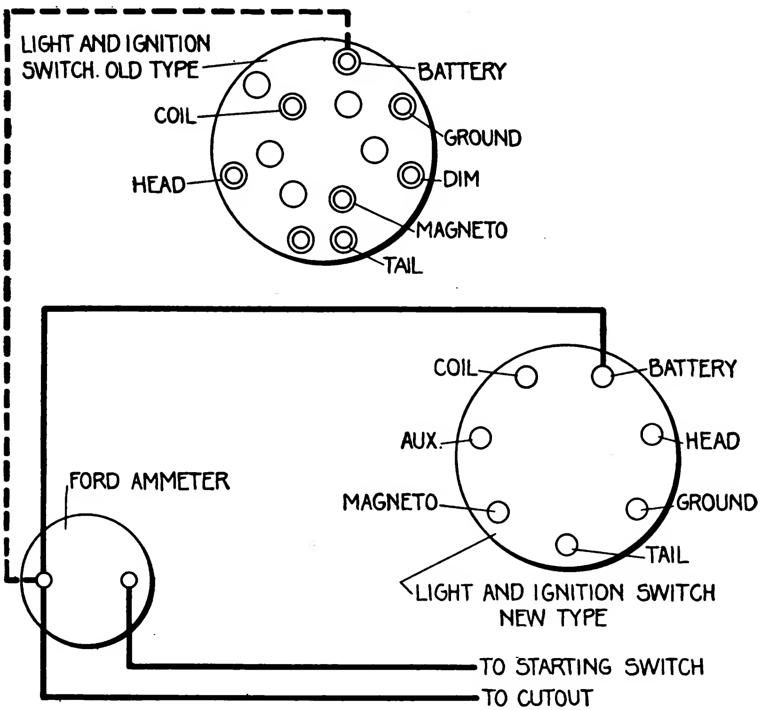


Fig. 104. Wire Connections on Round-Type Switches

small bulbs in the headlights will burn. With the handle in the **ON** position, the tail light and the large headlight bulbs will burn. The late cars are equipped with Tulite or double filament bulbs.

If switch troubles occur, the entire panel on which the ammeter and the switch are mounted may be removed from the front by taking out the four screws in the panel. The entire rear cover may be removed from the switch in order to look for shorts in this instrument; it will also be well to examine all wires lead-

ing to the instrument board to see that there are no shorts or grounds present.

HORN

Operation. The Ford horn is operated from the magneto and works on the vibrating principle. Its action is similar to that of the vibrator on the ignition coils, but the vibrator strikes the pin in the center of the horn diaphragm and causes the sound.

OPERATION OF FORD CAR

Introduction. The mechanical and electrical principles and troubles of the Ford car having been considered, the reader should now be able to understand more thoroughly this car's operation.

Operation does not mean the mere pressing of pedals and pulling of levers; it means also the why and wherefore of these actions and a knowledge of what is taking place inside the motor, the transmission, the rear axle, etc., when the various pedals and levers are moved. Then, and then only, can the driver hope to become proficient in the operation of his car.

Preliminary Inspections. *Cooling System.* Before trying to start the engine, the radiator should be examined to see that it is full of clean water. If perfectly clean water is not obtainable, it is advisable to strain the available water through muslin or other similar material so that foreign matter will not get into the circulating system and obstruct the small passages in the radiator.

The cooling system holds approximately 3 gallons of liquid. It is very important that the cooling system be filled before the motor is operated as the motor will become too hot if this is not done. When the cooling system is completely filled, water will run out of the overflow pipe.

The motor will naturally use more water during the first few days of its operation—because it is a new motor—as during this time the parts are fitting themselves to each other and more heat is naturally developed. If it is possible to secure rain water, by all means do so, for rain water does not contain alkalies or minerals which tend to deposit sediment and start corrosion in the cooling system. A phantom view of the cooling system is shown in Fig. 105.

Gasoline Supply. The gasoline tank should next be examined to see that there is a sufficient supply of fuel. In filling the tank, the gasoline should always be strained, preferably through chamois skin, as this prevents water and other substances from getting into the tank. Dirt or water in the gasoline is sure to cause

Fig. 105. Phantom View of the Ford Cooling System

trouble. The small vent hole in the gasoline-tank cap should not be allowed to get plugged up as this would prevent the proper flow of the gasoline to the carburetor. There is a drain cock at the bottom of the tank which may be opened to allow the removal of sediment or foreign substances which collect in a dirt trap

above the drain cock. The capacity of the gasoline tank when full is about 10 gallons. A sectional view of the fuel system is shown in Fig. 106.

Oil Supply. The supply of oil should next be inspected. There are two pet cocks underneath the car in front of the flywheel housing which are used as gages to show the supply of oil in the reservoir. The upper cock should be opened and a medium grade of good oil poured into the breather pipe until the oil flows out of this cock. After the engine has been limbered up, best results will be obtained by carrying the oil level midway between the two cocks, but it should be borne in mind at all times that, under no circumstances, should the oil be allowed to get below the lower cock.

Control Levers. The next move is to examine the control levers, which are located underneath the steering wheel.

The right-hand lever controls the throttle and is used to regulate the amount of gas vapor allowed to pass into the cylinder. When the engine is in operation, the farther this lever is moved down, the faster the engine will run and the greater will be the power developed. The throttle lever should be opened about five or six notches. This position varies according to the setting of the carburetor and the condition of the motor; a little experience will rightly determine the best position for each individual car.

The left-hand lever controls the time that the spark occurs in the cylinder in relation to the position of the piston. By pulling this lever down, the spark is advanced and by moving the lever up, the spark is retarded. In setting the levers before starting the motor, the spark should be put in about the third or fourth notch of the quadrant.

The hand lever which comes through the floor boards at the driver's left should be inspected to see that it is pulled all the way back as it holds out the clutch when in this position, thereby disconnecting the motor from the rear axle; at the same time it applies the emergency brake at the rear wheels.

Starting the Motor. *Car with Starter.* The ignition-switch key should then be inserted in the switch and turned to the battery position (if the car is equipped with a starting and light-

Fig. 106. Sectional View of the Ford Carburetion System

ing system at the factory). The choker should be pulled out if the motor is cold and held in this position while the starter button is depressed.

Fig. 107. Dash View of Cars not Equipped at the Factory with a Self-Starter

The storage battery then furnishes energy to the starter, thereby cranking the motor at a rate of speed sufficient to start

its operation. If the motor does not start at once, do not hold out the choker, as this will flood the combustion chambers with too rich a mixture; if the motor starts and then stops, this is an indication that the motor has either been starved or flooded. A cloud of heavy black smoke having a gassy smell will come out of the muffler if the motor has been given too rich a mixture.

Car without Starter. If the car is not equipped with an electric starter, it will be necessary to hold out the choke rod which projects through the front of the radiator while the motor is being cranked. It is also advisable to open the needle valve, say $\frac{1}{4}$ turn, until the motor is warmed up. This is especially

Fig. 108. Dash View of Cars Equipped with Self-Starter

true during cold weather. If the motor as a rule is very hard to start during the winter months, a good method to use is to crank the motor several times with the ignition switch off, holding out the choke rod while so doing. Then turn on the ignition switch to the **MAG** position and crank the motor. When stopping the motor, it is common practice, especially in cold weather, to pull out the choke at the front of the radiator instead of turning off the ignition switch. This operation leaves a rich deposit of fuel in the combustion chamber which will cause the motor to start much easier. The various control devices are shown in Fig. 107, while Fig. 108 shows the arrangement of the controls and instruments on the late models.

SPEED CONTROL

Clutch Pedal. There are three foot pedals that largely control the operation of the Ford Car. Of course, the throttle and the spark have a great deal to do with the speed of the car, but the foot pedals change the relation of the speed of the motor to that of the rear axle. The first pedal at the driver's left is for low and high speed, generally called the clutch pedal. When pressed forward, the clutch pedal engages the low-speed gears, causing the car to move very slowly but with great force, as the gear reduction is also great. This gear is also used when the car is traveling up a steep grade. When the clutch pedal is halfway forward, all gears are in neutral, being disconnected from the drive to the rear wheels, and when the hand lever is pulled halfway back, the clutch pedal will be held in the center, or neutral, position. When the clutch pedal is allowed to come all the way back —toward the driver—by pushing the hand lever forward, the clutch is thrown in, which causes the drive shaft to turn at the same speed as the motor. This is generally spoken of as direct drive, or high gear.

Reverse-Speed Pedal. The second, or center, pedal is used for reversing the motion of the car. When this pedal is depressed, the hand lever should be in the neutral position or, what amounts to the same thing, the clutch pedal should be held in the central position with the driver's left foot. The reverse pedal may then be depressed, which operation will cause the car to back up.

Brake Pedal. The right-hand pedal is used as a service brake, this brake being operated on the transmission drum; depressing the pedal causes the brakes to be applied.

Hand Lever. The purpose of the hand lever is to hold the clutch in the neutral position. If it were not for this lever, the driver would be compelled to stop the motor whenever he left the car. This lever also applies the emergency brakes at the brake drums on the rear wheels, thereby preventing the car from creeping forward when it is being cranked. The emergency brakes also hold the car when it is going up hill or standing at a curb or on an incline and are employed when it is desired to stop the car suddenly, etc. The brakes, however, are not operated until the lever is pulled back the entire distance. When the lever

is in a halfway position, or almost vertical, the clutch is thrown out, and when it is placed all of the way forward the clutch is engaged, driving the drive shaft direct. When the car is to be reversed, this lever should be placed in a central position as this will prevent the clutch from dropping into high gear. See Fig. 107 for the position of these pedals.

Starting the Car. After the motor is started and it is intended to make the car move, the driver should gradually depress the clutch, or low-speed, pedal, thus bringing the low-speed gears into operation. It is best to throw the hand lever all the way forward, at the same time holding the low-speed pedal in the neutral position, before the low-speed pedal is depressed, as this operation will then eliminate any further movement of the hand lever until the car is stopped.

After the car has gained sufficient headway, say 20 or 30 feet, the throttle should be slightly closed and the foot removed from the clutch pedal, allowing it to come all the way back and engaging the clutch, thus causing the car to be operated in direct drive. The speed of the car is now controlled by opening or closing the throttle. The low-speed gear should never be used except when necessary, although it is not advisable to cause undue strain on the motor in order to prevent the low-speed gears from being used.

Stopping the Car. When the driver desires to stop the car, the high-speed clutch is released by pressing the clutch pedal forward to the neutral position. The foot brakes should then be slowly applied until the car comes to a dead stop. It is necessary to pull the hand lever in the neutral position before the driver removes his foot from the clutch pedal. If this is not done, the high-speed clutch will be engaged and the motor will stall.

Before stopping the motor, the throttle should be opened a little and then the ignition switch should be turned off. This allows the motor to stop with the cylinders full of fresh gas, thus enabling it to start very easily.

Spark lever. The spark lever is controlled by the left hand and should be placed in such a position that the engine will not knock; this position should be as far advanced as possible. If the spark is too far advanced, a dull knock will be heard in the

motor. This knock is caused by the explosion occurring before the piston of the engine has completed its compression stroke. The very best results are obtained when the spark occurs at a position as far advanced as possible without knocking. The spark should be retarded only when the engine slows down on a heavy road or a steep grade. Care should be exercised not to retard the spark too far, since when the spark is late, a slow burning of the gas with excessive heat will result instead of getting the full power from the explosion.

The greatest economy in operation is obtained by driving with the spark advanced sufficiently to obtain the maximum speed with a given throttle opening. After a little experience, the driver will become accustomed to manipulating the spark automatically with excellent results.

Throttle. The throttle is controlled by the right hand and is used to increase the speed of the car to meet the various road and speed conditions. It is seldom necessary to use low gear except to give the car momentum in starting; therefore, practically all the running speeds needed for ordinary travel may be obtained on high gear. The speed of the car may be temporarily slackened when driving through crowded streets and highways by slipping the clutch. This slipping is accomplished by partially depressing the high speed or the clutch pedal. This operation, however, should be used as little as possible as it causes excessive wear on the clutch plates.

AUXILIARY SYSTEMS

Cooling System. The Ford motor is cooled by the thermosiphon system as explained on page 6, Part I. In cold weather it is very important to prevent the cooling system from freezing, as this will cause a great deal of damage by bursting the radiator tubes and possibly cracking the cylinders or the water jackets. To guard against freezing, a solution of denatured alcohol may be used to good advantage. Table III gives the different mixtures of alcohol and water and the freezing points of each.

A solution of 30 per cent alcohol, 60 per cent water, and 10 per cent glycerine is commonly used, its freezing point being the same as No. 2 solution, 8 degrees below zero. The alcohol in the

TABLE III

Anti-Freezing Solutions

Solution		Freezing Points
Alcohol	Water	
20%	80%	15° above zero
30%	70%	8° below zero
50%	50%	34° below zero

alcohol-water solution tends to vaporize, and it is therefore necessary to take due caution to see that the solution is up to its proper strength.

An instrument is now on the market known as the Radiatometer, Fig. 109, which tests the gravity of the cooling fluid in much the same way as the gravity of the electrolyte in a storage cell is tested. The percentage of the mixture is easily ascertained when the gravity is known.

Charging System. When the car has attained a speed of about 10 miles per hour in high gear, the ammeter on the dash should show **CHARGE.** This ammeter indication will increase until the car has reached a speed of about 20 miles per hour. At higher speeds this charge will taper off, this being a characteristic of the third-brush generator, as described on page 93. When the speed of the car has reached approximately 15 miles per hour, the generator should show a charge of from 10 to 12 amperes with all the lights off. When the lights are turned on, the charging rate as indicated by the ammeter will drop to about 5 or 6 amperes as the generator is furnishing current to the lights.

Fig. 109. Radiatometer

Care of Battery. The storage battery is a very important instrument in any car and it should be carefully examined and a hydrometer reading taken every week, as this reading indicates the condition of the charge. A hydrometer reading is shown in Fig. 110. A battery charged the same amount will have different

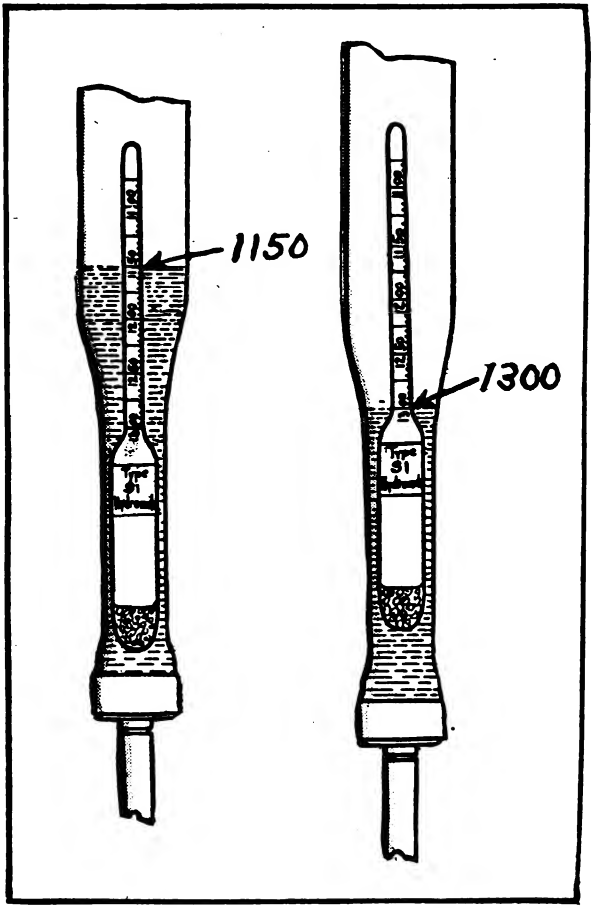


Fig. 110. Hydrometer Readings of a Half and a Fully Charged Cell

readings in tropical climates where water never freezes than it has in other localities. Table IV shows the relation of the readings to the amount of charge in the battery.

The hydrometer test should not be taken immediately after the battery is filled with water, as this procedure will not give an

TABLE IV

State of Charge of Battery

Gravity		Amount of Charge
Tropical Climate	Cool Climate	
1.200	1.275	full
1.175	1.250	three-quarter
1.150	1.225	one-half
1.125	1.200	one-quarter
1.100	1.150	full discharge

accurate reading. It is necessary for the battery to charge some little time after water is supplied before the reading is taken so that the acid will be thoroughly mixed. The battery should not be discharged below one-half charge. When it is in this condition, it should be taken to a battery station and recharged. In case of emergency, it is possible to allow the battery to fall to three-fourths discharge, but this is not good practice and the battery should be placed on charge as soon as possible. If the motor is operated without using the starter, the gravity of the cells will be raised.

If a battery goes dead, the cause of this condition should be located before the recharged battery is installed, as it is quite possible that a short or ground is present in the system; also make sure that the generator is charging properly. When the reading of one particular cell is more than fifty points different from the others, it indicates that this cell is not in good order and the battery should then be taken to a service station for attention.

Distilled water should be added at least once a week if the electrolyte is not covering the plates. During cold weather this water should be added only before the car is to be operated as it is likely to freeze if put in at any other time.

GENERAL INFORMATION

Cooling System. The cooling system of the Ford motor has a capacity of 14 quarts. The inlet hose is 1¾ inches in diameter and 2¾ inches long; while the outlet hose is 2 inches in diameter and 3¼ inches long. The hose clamps for the inlet hose are 2⅛ inches in inside diameter, and the outlet hose is 2½ inches inside diameter.

Transmission Band Linings. The transmission and brake lining is $\frac{3}{16}$ inch thick, $1\frac{1}{8}$ inches wide and 23 inches long. Three of these strips are required, making a total of 69 inches.

Transmission Repairs. Dismantle and clean all parts. See that all magnet clamps are tight and that magnets are parallel. Try the triple gear shafts for looseness in the flywheel; if loose, replace them with oversized shafts. Examine the triple gears for worn or loose rivets; if the rivets are not tight, peen them; if very loose, they should be replaced.

Rebushing. Try the triple gears on the shafts; if there is over .005 inch play in the bushings, they should be rebushed. When rebushed, the flange face of the new bushings should not project over .005 inch to .007 inch from the side of the triple gears. Examine the lugs on the inside of the brake drum; if they are worn or cut over $\frac{1}{32}$ inch deep on both contact sides, the drum should be scraped. If the driven-gear sleeve flange-bushing face is badly worn or too thin, it should be replaced.

Bushing Clearance. The gear shaft should be fitted to the driven-sleeve bushings to a clearance of .003 inch on a new job and on a repair job, a clearance of .005 inch. Examine the rivets on the slow-speed drum, making sure that they are tight. Also inspect the gears for worn or chipped teeth and test the clearance of the slow-speed drum on the driven-gear sleeve. There should be a clearance of .003 inch on a new job and .005 inch on a repair job.

Reverse Drum Clearance. Examine the rivets and the gear teeth on the reverse drum. Try the fit between the drum teeth and the low-speed gear as there should be a clearance of .003 inch on a new job and .005 inch on a repair job. Examine the driven gear to see if it is in good condition and try the keys in the keyways on the gear sleeve and the driven gear. Place and drive the driven gear on the driven-gear sleeve—the outer face on the driven gear should be about .010 inch below the end of the driven-gear sleeve. After assembling, see that all of the gears revolve freely. Assemble the gear shaft to the flywheel; then place the drum assembly, driven gear up, on the bench.

Triple Gear Assembly. Note the punch marks on the triple gears. Assemble the triple gears to the drum gear assembly with

the punch marks registering on the triple gears. Assemble the triple gears to the drum-gear assembly, taking note that the punch marks on the triple gears are facing toward the driven gear.

Setting Triple Gears. The setting of the gears may start at any point on the driven gear. The other two triple gears are now spaced by the punch marks, 9 teeth apart, or at 120 degrees from each other. After the triple gears are assembled to the drum assembly, tie a small cord around them so that they will be held in their relative position.

Placing Gear Unit. Pick up the complete gear unit and place the gears down and over the gear shafts and the triple-gear pins. Place the Woodruff keys that hold the disc drum in the gear shaft; the disc drum should then be driven on securely. Place and spread the cotter key so that the set screw does not loosen up and see that the drums are free and that there is not over $\frac{1}{32}$ inch end play in the brake drum. This is very important.

Clutch Assembly. The clutch discs should then be assembled. Place a large disc on first, then a small one until 25 are used, ending with a large one. Replace the push ring and try the fit of the drive plate bushing on the gear shaft; there should be .003 inch clearance on a new job and .007 inch on a repair job.

Fastening Drive Plate. Release the tension on the clutch fingers by compressing the clutch spring and placing the drive-plate cap screw under the clutch shift. The drive plate is then placed in position and fastened down; now remove the temporary drive-plate screw under the clutch shift, also the wire from one drive-plate screw to another. When the clutch is properly adjusted, there should be $\frac{13}{16}$ inch space between the lower side of the clutch and the drive plate. Fig. 111 is a sectional view of the assembled transmission.

Timing Gears. There are 42 teeth on the cam gear, this gear having a diameter of $5\frac{1}{3}$ inches; while the crankshaft gear has 21 teeth and is $2\frac{2}{3}$ inches in diameter. The ratio of these gears is 2 to 1.

Rear Axle Gears. The bevel gear in the rear axle has 40 teeth and the pinion has 11 teeth. The gear ratio is $3\frac{7}{11}$ to 1. When the car is being operated in low speed, the gear ratio between the motor and the rear wheels is 10 to 1; and when reverse speed is used, the ratio is 14.5 to 1.

Alignment of Front Wheels. The front wheels of the car are
heels
in of
ould

Fig. 111. Sectiona View of the Ford Transmission

be $\frac{1}{4}$ inch closer together at the front than at the back. If a plumb line is dropped through the spindle bolt it should touch the ground $2\frac{1}{16}$ inches from the center of the tire.

Clutch. The clutch has 12 small discs and 13 large discs. A large disc should always be on top when the clutch is assembled.

TABLE V

Magneto Output

R.P.M.	Miles per Hour		Volts	Amperes	Cycles per Second
	Car	Truck			
200	5	2.63	0.5	6.1	26.4
400	10	5.26	9.8	7.9	52.8
600	15	7.89	14.4	8.5	80.0
800	20	10.52	18.8	8.8	106.4
1000	25	13.15	22.8	8.9	146.4
1200	30	15.80	26.2	9.0	160 0

Valves. The valves are $1\frac{1}{2}$ inches in diameter at the head, having a seat at an angle of 45 degrees to the stem. The valve stem is $\frac{5}{16}$ inch in diameter and $5\frac{1}{8}$ inches long. There is a pin-hole $\frac{5}{8}$ inch from the end of the valve stem, this hole being $\frac{3}{32}$ inch in diameter. The exhaust and the inlet valves are of the same size and they are interchangeable.

Valve Timing. The valves should be timed by the position of the piston. The measurements for the different models are as follows:

Models previous to 1913

Exhaust opens $\frac{3}{8}$ inch before lower dead center
Exhaust closes $\frac{1}{64}$ inch past upper dead center
Intake opens $\frac{7}{64}$ inch past upper dead center
Intake closes $\frac{3}{8}$ inch past lower dead center

Models later than 1913

Exhaust opens $\frac{5}{16}$ inch before lower dead center
Exhaust closes upper dead center
Intake opens $\frac{1}{16}$ inch past upper dead center
Intake closes $\frac{9}{16}$ inch past lower dead center

Magneto. In table V is given the output of the late type of Ford magneto at various motor speeds.

TROUBLE SHOOTING

WHEN MOTOR FAILS TO START

Q. When the engine fails to start, what parts should be examined?

A. The first thing to do is to make sure that a sufficient supply of gasoline is at hand; also that there is no water mixed with the gasoline. If water is present, it may freeze at the outlet

of the tank and prevent the gasoline from flowing to the carburetor. If the temperature is not cold enough to freeze, the water will pass into the carburetor and the combustion chamber and possibly short the spark plugs.

Q. If the gasoline supply is in good condition, what should then be examined?

A. The ignition system should be examined to see that sufficient spark is present at the spark plugs at the proper time. If the car is equipped with a starter, the ignition switch should be turned on and the starter button depressed, shorting the spark plugs with a screw driver or a hammer. The fact that the vibrator coils are operating does not necessarily indicate that a spark is present of sufficient strength to prope ignite the mixture. Wl the plugs are shorted this method, a sp should jump at leas inch to the screw dri or hammer.

Q. If no spark c very weak spark is pr ent, what should be spected?

Fig. 112. Oiling the Timer

A. During co weather, the timer should be examined as congealed oil or water may have collected in the timer, preventing suitable contact from being made with the segments and the roller. The timer is easily removed by loosening up the cap screw on the timing-gear case, and after it has been thoroughly cleaned, it should be supplied with a little oil by the method shown in Fig. 112. The spring on the timer roller may also be broken; and this will prevent a contact from being made. The timer should be carefully inspected as well as the surface of the commutator, as a rough commutator is likely to prevent the motor from starting and it is sure to cause the motor to miss after it is started. More detailed information on the timer can be found on page 86.

Q. If the timer is in good condition, what should then be examined?

A. Examine the vibrator points on the coils for they may be adjusted too closely. If the car is equipped with a battery supply for the ignition system, the switch should be turned to the battery position and the motor turned over until a coil starts to vibrate. The vibrator adjustment should then be changed until a strong spark is produced at the secondary terminal. Of course, if the battery is weak, it will be impossible to make this adjustment.

Q. After adjusting the coils and the motor does not start, what should be examined?

A. The compression of each cylinder should then be carefully tested, using the crank for this operation. Try each cylinder by placing the crank on each quarter of the shaft and rocking the motor, thus ascertaining the relative compression of the various cylinders. If the compression is poor, the cylinders may be full of carbon; this may cause the valves to remain open, thus losing the compression through them.

WHEN ENGINE LACKS POWER AND RUNS IRREGULARLY

LOW SPEED

Q. If the engine misses at low speeds and does not develop much power, what should be examined first?

A. The compression of the motor should be examined by the method described under "When Engine Fails to Start."

Q. If the compression is in good condition, what then?

A. The carburetor may not be properly adjusted; the adjustment of this instrument determines to a great extent the power produced by the motor. If the carburetor is set too rich, the mixture will burn very slowly, developing less power than it should; and if the carburetor is set too thin, the mixture will burn still more slowly than the rich mixture, and this will also greatly decrease the power.

Q. If the carburetor adjustment is correct, what part of the motor should then be examined?

A. The spark plugs should then be examined as it is quite possible that they are partially or completely shorted.

Q. After the spark plugs are clean and the motor still misses, what parts should be inspected?

A. The vibrator points on the spark coils should then be examined as it is possible that they have become pitted, causing a high resistance in the path of the current, thus decreasing the strength of the spark in the secondary winding.

Q. After the ignition has been carefully looked over and everything found in good condition, what should be examined?

A. The clearance between the valve stem and the push rod may be insufficient to allow the valves to seat properly, thus holding them open and allowing the motor to miss intermittently.

HIGH SPEEDS

Q. When the motor lacks power and runs irregularly at high speeds, what should be examined?

A. The spark plugs should first be examined, as it is quite possible that the spark gap is too wide; perhaps the plugs may be partially fouled, either on account of a porous or a cracked porcelain or because of oil and carbon on the porcelain.

Q. With spark plugs in good condition and the motor still missing, what should be examined next?

A. The commutator should be carefully inspected as the timer may be worn, thus causing the roller to jump over some segments and to strike others. Missing the segments will naturally prevent a spark from occurring in the cylinder.

Q. If the commutator is in good condition, what other part should be examined?

A. It is quite possible that some of the valve springs may be so weak that they will prevent the valves from properly seating; or the valve stems may be coated with a gummy carbon, causing the valves to stick and thus lose compression.

Q. If the valves, commutator, and spark plugs are in good condition, what else would be likely to cause an irregular miss at high speeds?

A. If the carburetor is improperly adjusted or the gas line is clogged so that the gasoline is supplied in an insufficient quantity to furnish a perfect mixture, the motor will have a tendency to miss at high speeds. The vibrator points should also be examined.

WHEN ENGINE STOPS SUDDENLY

Q. When the engine stops suddenly after back-firing in the intake manifold, what is the first thing to do?

A. The gasoline tank should be examined as it is likely that the supply has become exhausted.

Q. If there is sufficient gasoline, what should be done?

A. The drain cock at the bottom of the gas tank should be opened and any sediment in the dirt trap removed. The drain cock on the carburetor should also be opened, allowing any dirt that has accumulated in the float chamber to drain out, as water or any foreign substance is likely to clog up the spray nozzles, foul the spark plugs, and stop the motor.

Q. If gasoline is running out of the carburetor when the motor stops, what does this indicate?

A. This condition indicates that the float has stuck, thus allowing the float valve to remain open. The gasoline then flows into the float chamber unobstructed, and this condition will cause the motor to stop by choking it with too rich a mixture. A leaky float valve may also be responsible for this trouble.

Q. After the carburetion system has been carefully examined and everything found to be in good condition, what should then be inspected?

A. The ignition wires leading to the switch, the magneto, the coils, and the timer should then be carefully examined, as a loose or broken wire will easily prevent the motor from operating. It is less likely to be in the timer connections than at the other places mentioned, as it would be less likely for all the timer wires to be broken or shorted, which would prevent the motor from starting. The spring on the timer roller should also be examined to see if it is broken.

Q. When the car stops because the motor is very hot, what should be examined?

A. The supply of oil and water should first be examined as it is quite possible that either one has been exhausted.

IF ENGINE OVERHEATS

Q. If the engine continually overheats, what may cause this trouble?

A. If there is lack of water in the radiator or of oil in the crankcase, the motor is bound to overheat; also the fan belt may

Fig. 113. Construction of the Bendix Drive on the Starting Motor

be slipping or loose, which would prevent the fan from being driven at its proper rate of speed.

Q. Will carbon cause the motor to overheat?

A. Yes; the formation of carbon in the combustion chambers prevents the heat from being properly distributed, and this will naturally raise the temperature of the motor to a certain extent. If carbon is present in the combustion chambers, it should be removed either by taking off the head and scraping the carbon from the parts or by using the oxygen-burning method.

Q. If there is a good supply of oil and water, if the fan belt is in good condition, and if there is absence of carbon in the cylinders, what then would be likely to cause the motor to overheat?

A. If the spark is too far retarded, the explosion will occur too late in the cylinders, thus causing more heat to be developed, as the gas does not burn so fast when exploded after the proper time. If the carburetor is set too rich, a great deal of extra heat will also be developed which will have a tendency to overheat the entire motor. Then again, the water-circulation system may be clogged up on account of sediment in the radiator.

GENERAL TROUBLES

Q. What is the trouble when the starter button is depressed and the starter armature merely spins but does not engage the starter pinion with the flywheel?

A. This trouble is undoubtedly due to a broken drive spring, this spring being shown in Fig. 113. When this spring is broken, the armature shaft will turn inside the screw shaft, but as the armature shaft is connected to the screw shaft through the drive spring, the drive pinion will naturally be unable to turn.

Q. What causes the motor to fail to start after being stopped for a short time when the carburetor seems to work well and there is a hot spark? Why will the motor start at once if the needle valve is turned off and the motor is spun after it has been standing for a time?

A. Most of the trouble is due to a rich carburetor mixture. By opening the pet cocks more air is let into the cylinder and a thinner mixture obtained for starting. The adjustment of the carburetor should be changed to obtain a thinner mixture, and

if the float level is too high it should be adjusted. The spark-plug points should also be set to make a gap $\frac{1}{32}$ inch wide.

Q. Is there any way to adjust the generator of a 1919 Ford to make it charge the battery at a higher rate?

A. The charging rate of this generator can be adjusted by shifting the position of the third brush. If this brush is moved in the same direction as the armature rotates, the charging rate will be increased; if it is moved in the opposite direction, the rate will be decreased. Never charge above 12 amperes.

Q. If the ammeter shows a charge of 8 amperes when the car is traveling at 25 m.p.h. with the lights off, and when the headlights are turned on, it shows a discharge of 10 amperes, what is the trouble?

A. A 10-ampere discharge rate when the headlights are turned on is entirely too much. It indicates that there is a short-circuit in the lighting system. When the engine is not running and all the lights are burning, the ammeter should show 5.4 amperes discharge, or with the dimmer and tail lamps burning, there should be a discharge of 1.25 amperes.

Q. What is the trouble with a Ford car when it misses on all four cylinders when a steep grade is encountered?

A. The trouble is undoubtedly due to weak magnets which cause the coils to give a weak current whenever the car slows down under a load. Examine the coil vibrators as the points may be badly pitted; the spark-plug points should also be inspected as too wide a gap will cause this trouble. There may also be too wide a gap between the magnets and coils.

Q. What is meant by spark advance and spark retard?

A. Advancing and retarding the spark affect the time the spark takes place in the cylinder in relation to the position of the piston. If a spark occurs when the piston is at or past upper dead center, it is said to be retarded. If it occurs before dead center, the spark is advanced.

When cranking the motor very slowly with the ignition switch on BATT, the spark must be retarded to prevent an explosion from taking place in the cylinder before the piston has reached upper dead center. This explosion would reverse the motion of the motor and cause a kick. The amount of advance

to the spark when driving depends upon the speed of the motor. If the motor is pulling hard or turning over slowly, the spark can be advanced but very little. If, however, the motor is turning fast with a comparatively light load, then a full advance is advisable.

Q. How are the magnets of a Ford magneto recharged without removing them from the car?

A. To charge a Ford magneto without removing the magnets from the motor, it is first necessary to place the flywheel in the correct position. To do this, hold a compass near the magneto terminal 1 inch to the left of the terminal and 6 inches to the rear; that is, the center line of the engine should be 1 inch to the right of the center line of the compass, and the compass should be 6 inches back of the terminal plug. Turn the motor until the north pole of the compass points directly toward the front end of the car. Much of the success of the magnet charging depends on this setting, so it should be done carefully. The next step is to disconnect the terminal wire from the magneto plug. Connect the positive battery terminal to the magneto post and make several flash connections to the ground with the other battery terminal.

Q. What is the trouble when a Ford heats up after the car is run about a mile and when after running 5 miles the motor becomes so hot that the water boils and a great deal of power is lost?

A. The roller-brush assembly of the timer is probably worn to such an extent that the ignition is late or the advance lever is disconnected or broken so that the spark cannot be advanced. Although there is sufficient oil in the motor, the oil pipe may be clogged up and cause considerable heating trouble, as the oil will not properly circulate. The cooling system may be clogged, the radiator core painted with a high finish paint. The compression may be weak or there may be a carbon formation in the cylinders.

GLOSSARY

GLOSSARY

THE following glossary of automobile terms is not intended in any sense as a dictionary and only words used in the articles themselves have been defined. The definitions have been made as simple as possible, but if other terms unfamiliar to the reader are used, these should be looked up in order to obtain the complete definition.

A

A. A. A.: Abbreviation for American Automobile Association.

Abrasive: Any hard substance used for grinding or wearing away other substances.

Absorber, Shock: See "Shock Absorber".

Accelerate: To increase the speed.

Acceleration: The rate of change of velocity of a moving body. In automobiles, the ability of the car to increase in speed. Pickup.

Accelerator: Device for rapid control of the speed for quick opening and closing of the throttle. Usually in the form of a pedal, spring returned, the minimum throttle opening being controlled by the setting of the hand throttle.

Accessory: A subordinate machine that accompanies or aids a more important machine; as, a horn is an accessory of an automobile.

Accumulator: A secondary battery or storage battery. It usually consists of chemically prepared lead plates combined with an acid solution. Upon being charged with an electric current from a primary source, a chemical change takes place which enables the plates in their turn to give a current of electricity when used as a source of power, the plates at the same time returning to their original chemical state.

Acetone: A liquid obtained as a by-product in the distillation of wood alcohol, and used in connection with reservoirs for storing acetylene for automobile lights, as it dissolves many times its own volume of acetylene gas.

Acetylated Alcohol: Alcohol which has been denatured by the addition of acetylene, which also increases its fuel value. See "Alcohol, Denatured".

Acetylene: A gaseous hydrocarbide used as an illuminant; is usually generated for that purpose by the action of water on calcium carbide.

Acetylene Generator. A closed vessel in which acetylene gas may be produced by the action of water on calcium carbide and which supplies the gas under uniform pressure.

Acetylene Lamp: A lamp which burns acetylene gas.

Acetylite: Calcium carbide which has been treated with glucose. It is used to obtain a more uniform and slower production of acetylene gas than can be obtained with the untreated calcium carbide.

Acid: In connection with automobiles the term usually means the liquid or electrolyte used in the storage battery. See "Electrolyte".

Acid Cure. Method of rapid vulcanization of rubber without heat. Used in tire repairs. The agent is sulphur chloride.

Acidimeter. An instrument for determining the purity of an acid.

Active Material: Composition in grids that forms plates of a storage battery. It is this material in which the chemical changes occur in charging and discharging.

Adapter: Device by which one type of lamp burner may be used instead of the one for which the lamp was designed. Usually a fitting by which a gas or oil lamp may be converted into an electric lamp.

Adhesion: That property of surfaces in contact by virtue of which one of them tends to stick to the other. It is used as synonymous with friction. The adhesion of wheels acts to prevent slipping.

Adjustment: The slackening or tightening up of parts to compensate for wear, reduce friction, or secure better contact.

Admission: In a steam engine, the letting in of the steam to the cylinder; in gas engine, the letting in of mixture of gas and air to the cylinder.

Advanced Ignition: Usually called *advancing the spark*. Setting the spark of an internal-combustion motor so that it will ignite the charge at an earlier part of the stroke.

Advance Sparking: A method by which the time of occurrence of the ignition spark may be regulated, by completing the electric circuit at the earlier period.

Advancing the Spark: See "Advanced Ignition".

Aerodynamics: The science of atmospheric laws, i.e., the effects produced by air in motion.

After-Burning: Continued burning of the charge in an internal-combustion engine after the explosion.

After-Firing: An explosion in the muffler or exhaust passages.

A-h: Abbreviation for *ampere hour.*

Air Bottle: A portable container holding compressed air or carbon dioxide for tire inflation.

Air-Bound: See "Air Lock".

Air Compressor: A machine for supplying air under pressure for inflating tires, starting the motor, etc.

Air Cooled: Cooled by air direct. Usually referring to the cylinder of an engine, whose heat caused by the combustion within it is carried away by air convection and radiation.

Air Cooling: A system of dispersing by air convection the heat generated in the cylinder of an internal-combustion motor.

Air Intake: An opening in a carbureter to admit air.

Air Leak: Entrance of air into the mixture between carbureter and cylinder.

Air Lock: Stoppage of circulation in the water or gasoline system caused by a bubble of air lodging in the top of a bend in the pipe.

Air Pump: A pump operated by the engine or by hand to supply air pressure to the oil tank or gasoline tank; sometimes called *pressure pump.*

Air-Pump Governor: A device to regulate the speed of the air pump so as to give a uniform air pressure.

Air Resistance: The resistance encountered by a surface in motion. This resistance increases as the square of the speed, which makes it necessary to employ four times as much power in order to double a given speed.

Air Tube: See "Pneumatic Tire".

Airless Tire: Name of special make of non-puncturable resilient tire.

A. L. A. M.: Abbreviation for Association of Licensed Automobile Manufacturers, now out of existence.

A. L. A. M. Horsepower Rating: The horsepower rating of an automobile found by the standard horsepower formula approved by the Association of Licensed Automobile Manufacturers. Since the dismemberment of this organization, the formula is usually called the S.A.E. rating. This formula is h.p. = bore of cylinder (in inches) squared × No. of cylinders ÷ 2.5, at a piston speed of 1000 feet per minute.

Alarm, Low-Water: See "Low-Water Alarm".

Alcohol: A colorless, volatile, inflammable liquid which may be used as fuel for internal-combustion engines.

Alcohol, Denatured: Alcohol rendered unfit for drinking purposes by the addition of wood alcohol, acetylene, and other substances.

Alignment: The state of being exactly in line. Applied to crankshafts and transmission shafts and to the parallel conditions of the front and rear wheels on either side.

Alternating Current: Electric current which alternates in direction periodically.

Ammeter: An instrument to measure the values of current in an electric circuit directly in amperes. Also called *ampere meter.*

Amperage: The number of amperes, or current strength, in an electric circuit.

Ampere: The practical unit of rate of flow of electric current, measuring the current intensity.

Ampere Hour: A term used to denote the capacity of a storage battery or closed-circuit primary battery. A battery that will deliver three amperes for six hours is said to have an eighteen-ampere-hour capacity.

Ampere Meter: See "Ammeter".

Angle-Iron Underframe: An underframe constructed of steel bars whose cross section is a right angle.

Anneal: To make a metal soft by heating and cooling. To draw the temper of a metal.

Annular Gear: A toothed wheel upon which the teeth are formed on the inner circumference.

Annular Valve: A circular valve having a hole in the center.

Annunciator: An installation of electric signals or a speaking tube to allow the passengers in an enclosed car to communicate with the driver.

Anti-Freezing Solution: A solution to be used in the cooling system to prevent freezing in cold weather; any harmless solution whose freezing point is somewhat below that of water may be used.

Anti-Friction Metal: Various alloys of tin and lead used to line bearings, such as Babbitt metal, white metal, etc.

Anti-Skid Device: Any device which may be applied to the wheels of a motorcar to prevent their skidding, such as tire coverings with metal rivets in them, chains, etc.

Apron: Extensions of the fenders to prevent splashing by mud or road dirt.

Armature: In dynamo-electric machines, the portion of a generator in which the current is developed, or in a motor, the portion in which the current produces rotation. In most generators in automobile work, the armature is the rotating portion. In magnetic or electromagnetic machines the armature is the movable portion which is attached to the magnetic poles.

Armature Core: The iron portion of the armature which carries the windings and serves as part of the path for the magnetic flux.

Armature Shaft: The shaft upon and with which the armature rotates.

Armature Winding: Electrical conductors, usually copper, in an armature, and in which the current is generated, in case of a generator, or in which they produce rotation in a motor.

Artillery Wheel: A wheel having heavy wood spokes.

Aspirating Nozzle: An atomizing nozzle to make the liquid passing through it pass from it in the form of a spray.

Assembled Car: A car whose chief parts, such as engine, gearset axles, body, etc., are manufactured by different parts makers, only the final process of putting them together being carried out in the car-making plant.

Atmospheric Line: A line drawn on an indicator diagram at a point corresponding with the pressure of the atmosphere.

Atmospheric Valve: See "Suction Valve".

Atomizer: A device by which a liquid fuel, such as gasoline, is reduced to small particles or to a spray; usually incorporated in the carbureter.

Auto: (1) Popular abbreviation for automobile. (2) A Greek prefix meaning self.

Auto-Bus: An enclosed motor-driven public conveyance, seating six or more people; usually has a regular route of travel.

Autocar: A motorcar or automobile; a trade name for a particular make of automobile.

Auto-Cycle: See "Motorcycle".

Autodrome: A track especially prepared for automobile driving, particularly for races.

Autogenous Welding: See "Welding, Autogenous".

Auto-Igniter: A small magneto generator or dynamo for igniting gasoline engines, the armature of which is connected with the flywheel by gears or by friction wheels, so that electric current is supplied as long as the engine revolves.

Autoist: One who uses an automobile.

Automatic Carbureter: A vaporizer or carbureter for gasoline engines whose action is entirely automatic.

Automatic Cut-Out: See "Cut-Out, Automatic".

Automatic Spark Advance: Automatic variation of the instant of spark occurrence in the cylinder. Mechanical advancing and retarding of the spark to correspond with and controlled by variations in crankshaft speed.

Auto-Meter: Trade name for special make of combined speedometer and odometer.

Automobile: A motor-driven vehicle having four or more wheels. Some three-wheeled vehicles are properly automobiles, but are usually called *tricars.*

Automobilist: The driver or user of an automobile.

Auto Truck: A motor-driven vehicle for transporting heavy loads; a heavy commercial car.

Auxiliary Air Valve: Valve controlling the admission of air through the auxiliary air intake of a carbureter.

Auxiliary Air Intake: Opening through which additional air is admitted to the carbureter at high speeds.

Auxiliary Exhaust: Ports cut through cylinder walls to permit exhaust gases to be released from the cylinder when uncovered by the piston. These are sometimes used as an additional scavenging means for the regular exhaust valves.

Auxiliary Fuel Tank: See "Fuel Tank, Auxiliary".

Auxiliary Spark Gap: See "Spark Gap, Outside".

Axle: The spindle with which a wheel revolves or upon which it revolves.

Axle, Cambered: An axle whose ends are slanted downwards to camber the wheels.

Axle, Channel: An axle which is U-shaped in cross section.

Axle, Dead: Solid, fixed, stationary axle. An axle upon which the wheels revolve but which itself does not revolve.

Axle, Dropped: An axle in which the central portion is on a lower level than the ends.

Axle, Floating: A full-floating axle. A live axle in which the shafts support none of the car weight, but serve only to turn the wheels.

Axle, I-Beam: An axle whose cross section is in the shape of the letter I.

Axle, Live: An axle in which are comprised the driving shafts that carry the power of the motor to the driving wheels.

Axle, Semi-Floating: A live axle in which the driving shafts carry all of the car weight as well as transmitting the driving torque.

Axle, Three-Quarters Floating: A live axle in which the shafts carry a part of the weight of the car, while the housing carries the balance of the weight. It is intermediated by a floating axle and the semi-floating axle.

Axle, Trussed: An axle in which downward bending is prevented by a truss.

Axle, Tubular: An axle formed of steel tubing. Usually applied to the front axles, but sometimes used in referring to tubular shafts of rear axles.

Axle Casing: That part of a live axle that encloses the driving shafts and differential and driving gears. Axle housing.

Axle Housing: See "Axle Casing".

Axle Shaft: The member transmitting the driving torque from the differential to the rear wheels.

B

Babbitt: A soft metal alloy used for lining the bearings of shafts.

Back-Firing: An explosion of the mixture in the intake manifold or carbureter caused by the communication of the flame of explosion in the cylinders. Usually due to too weak a mixture. Popping.

Back Kick: The reversal of direction of the starting, caused by back-firing.

Backlash: The play between a screw and nut or between the teeth of a pair of gear wheels.

Back Pressure: Pressure of the exhaust gases due to improper design or operation of the exhaust system.

Baffle Plate: A plate used to prevent too free movement of a liquid in the container. In a gas engine cylinder, a plate covering the lower end of the cylinder to prevent too much oil being splashed into it. The plate has a slot through which the connecting rod may work.

Balance Gear: See "Differential Gear".

Balancing of Gasoline Engines: Insuring the equilibrium of moving parts to reduce the vibration and shocks.

Ball-and-Socket Joint: A joint in which a ball is placed within a socket recessed to fit it, permitting free motion in any direction within limits.

Ball Bearing: A bearing in which the rotating shaft or axle is carried upon a number of small steel balls which are free to turn in annular paths, called *races.*

Balladeur Train: A French name for a sliding change-speed gear.

Barking: The sound made by the explosions caused by after-firing.

Base Bearing: See "Main Bearing".

Base Explosion: See "Crankcase Explosion".

Battery: A combination of primary or secondary cells, as dry cells or storage cells.

Battery, Dry: See "Dry Battery".

Battery, Storage: See "Accumulator".

Battery Acid: The electrolyte in a storage battery.

Battery-Charging Plug: Power terminals to which the leads of a storage battery may be connected for charging the battery.

Battery Gage: (1) Voltmeter or ammeter or voltammeter for testing the specific gravity of the electrolyte in a secondary battery.

Battery Syringe: A syringe used to draw out a part of the electrolyte or solution from a storage battery cell to test its density and specific gravity.

Baumè: A scale indicating the specific gravity or density of liquids and having degrees as units. Gasoline of a specific gravity of .735 has a gravity of 61 degrees Baumé.

Bearing: A support of a shaft upon which it may rotate.

Bearing, Annular Ball: A ball bearing consisting of two concentric rings, between which are steel balls.

Bearing, Ball: A bearing in which the rotating shaft and the stationary portion of the bearings are separated from sliding contact by steel balls. A steel collar fitted to the shaft rolls upon the balls, which in turn roll upon steel collar attached to the stationary portion of the bearing.

Bearing, Cup and Cone: A ball bearing in which the balls roll in a race, which is formed between a cone-shaped fixed collar and a cup-shaped shaft collar.

Bearing, Main: The bearing in which rotates the crankshaft of an engine.

Bearing, Plain: A bearing in which the rotating shaft is in sliding contact with the bearing supporting it.

Bearing, Radial: A bearing designed to resist loads from a direction at right angles to the axis of the shaft.

Bearing, Roller: A bearing in which the journal rests upon, and is surrounded by, hardened steel rollers which revolve in a channel or race surrounding the shaft.

Bearing, Thrust: A bearing designed to resist loads or pressures parallel with the axis of the shaft.

Bearing Cap: That portion of a plain bearing detachable from the stationary portion, and which holds the bearing bushing and shaft.

Bearing Surface: The projected area of a bearing in a perpendicular plane to the direction of pressure.

Beau de Rochas Cycle: The four-stroke cycle used in most internal-combustion engines. This cycle was proposed by M. Beau de Rochas and put into practical form by Dr. Otto. See "Four-Cycle".

Belt and Clutch Dressing: A composition to be applied to belts and clutches to prevent them from slipping.

Belt Drive: A method of transmitting power from the engine to the countershaft or jack shaft by means of belts.

Benzine: A petroleum product having a specific gravity between that of kerosene and gasoline. Its specific gravity is between 60 degrees and 65 degrees Baumé.

Benzol: A product of the distillation of coal tar. Coal tar benzine. Used as a rubber solvent and in Europe as a motor fuel.

Berline Body: A limousine automobile body having more than two seats in the back part.

Bevel-Gear: Gears the faces of whose teeth are not parallel with the shaft, but are on a beveled edge of the gear wheel.

Bevel-Gear Drive: Method of driving one shaft from another at an angle to the first. The chief method of transmitting the drive from the propeller shaft to the rear axle shafts.

B. H. P.: An abbreviation for brake horsepower.

Bicycle: A two-wheeled vehicle propelled by the pedaling of the rider.

Binding Posts: See "Terminals".

Bleeder: A by-pass in the sight-feed of a mechanical oiling system by which the oil delivered through that feed is allowed to pass out instead of going to the bearings.

Blister: A defect in tires caused by the separation of the tread from the fabric.

Block Chain: A chain used in automobiles, bicycles, etc., of which each alternate link is a steel block.

Blow-Back: The backward rushing of the fuel gas through the inlet valve into the carbureter.

Blower Cooled: A gas engine cooled by positive circulation of air maintained by a blower.

Blow-Off: A blow-out caused by the edge of the bead of tire becoming free from the rim and allowing the tube to protrude through the space thus formed.

Blow-Out: The rupture of both the inner tube and outer casing of a pneumatic tire.

Blow-Out Patch: See "Patch, Tire Repair".

Body: (1) The superstructure of an automobile; the part that resembles and represents the body of a horse-drawn vehicle. (2) In oils, the degree of viscosity. The tendency of drops of oils to hang together.

Body Hangers: Attachments to or extensions of the frame for holding the body of the vehicle. They should be properly called frame hangers.

Boiler: A vessel in which water is evaporated into steam for the generation of power.

Boiler, Fire-Tube: A tubular steam boiler in which the end plates are connected by a number of open ended thin tubes, the spaces around which are filled with water, the hot gases passing through the tubes.

Boiler, Flash: A steam boiler in which steam is generated practically instantaneously. There is practically no water or steam stored in the boiler. A flash generator.

Boiler, Water-Tube: A steam boiler in which the water is carried in metal tubes, around which the hot gases circulate.

Boiler Alarm: See "Low-Water Alarm".

Boiler Covering: A non-conducting substance used as a covering for boilers to prevent loss of heat by radiation.

Boiler-Feed Pump: An automatic and self-regulating pump for supplying a boiler with feed water.

Boiler-Feed Regulator: A device to make the feed-water supply of the boiler automatic.

Bonnet: (1) The hood or metallic cover over the front end of an automobile. See "Hood". (2) The cover over a pump-valve box, or a slide-valve casing. (3) A cover to enclose and guide the tail end of a

steam-engine-valve spindle or the cover of a piston-valve casing. (4) The pan underneath the engine in an automobile.

Boot: A covering to protect joints from dirt and water or to prevent the leakage of grease. (2) Space provided for baggage at the rear of a car.

Bore: The inside diameter of the cylinder.

Boss: An enlarged portion of a part to give a point for attachment of another part.

Bottom: The meshing of gears without clearance.

Bow Separator: A part to prevent chafing of the bows of a top when folded.

Boyle's Law of Gases: A law defining the volume and pressure of gases at constantly maintained temperatures. It states that the volume of a gas varies inversely as the pressure so long as the temperature remains the same; or, the pressure of a gas is proportional to its density.

Brake: An apparatus for the absorption of power by friction, and by clamping some portion of the driving mechanism to retard or stop the forward motion of the car.

Brake, Air-Cooled: A brake whose parts are ridged to present a large surface for transferring to the air the frictional heat generated in them.

Brake, Band: A brake which contracts upon the outside of a drum attached to some part of the driving mechanism.

Brake, Constricting Band: A form of brake applied by tightening a band around a pulley or drum.

Brake, Differential: A brake acting upon the differential gear.

Brake, Double-Acting: A brake which will hold when the drum is rotating in either direction.

Brake, Drum, and Band: See "Brake, Band".

Brake, Emergency: A brake intended to be used in case the service brake does not act to a sufficient extent.

Brake, Expanding-Band: A drum brake in which the braking force is exerted by a band forced outward against the inner rim of a pulley.

Brake, External-Contracting: A brake consisting of a drum affixed to a rotating part, the outer surface of whieh is encircled by a contracting band.

Brake, Foot: A brake designed to be operated by the driver's foot. A pedal brake. Usually the service brake.

Brake, Front-Wheel: A brake designed to operate on the front wheels of the car.

Brake, Gearset: A brake designed to act on the transmission shaft and attached to the gearbox.

Brake, Hand: A brake designed to be operated by means of a hand lever. Usually the emergency brake.

Brake, Hub: A brake consisting of a drum secured to one of the wheels. This is the usual type.

Brake, Internal: A brake in which an expanding mechanism is contained within a rotating drum, the expansion bringing pressure to bear on the drum.

Brake, Internal-Expanding: A brake consisting of a drum, against the inside of which may be expanded a band or a shoe.

Brake, Motor: A brake in an electric vehicle which acts upon the armature shaft of the motor.

Brake, Service: A brake designed to be used in ordinary driving. It is usually operated by the driver's foot.

Brake, Shoe: A brake in which a metal shoe is clamped against a revolving wheel.

Brake, Transmission: A brake designed to act upon the transmission shaft.

Brake, Water-Cooled: A brake through which water may be circulated to carry off the frictional heat.

Brake Equalizer: A mechanism applied to a system of brakes operated in pairs to assure that each brake shall be applied with equal force.

Brake Horsepower: The horsepower supplied by an engine as shown by the application of a brake or absorption dynamometer.

Brake Housing: A casing enclosing the brake mechanism.

Brake Lever: The lever by which the brake is applied tc the wheel.

Brake Lining: The wearing surface of a brake; usually arranged to be easily replaced when worn.

Brake Pedal: Pedal by which the brake is applied.

Brake Pull Rod: A rod transmitting the tension from the lever or pedal to the movable portion of the brake proper.

Brake Ratchet: A device by which the brake lever or brake pedal can be set in position and retained there; usually consists of a notched quadrant with which a movable tongue on the lever head or pedal engages.

Brake Rod: The rod connecting the brake lever with the brake.

Brake Test: A test of a motor by means of a dynamometer to determine its power output at different speeds.

Braking Surface: The surface of contact between the rotating and stationary parts of a brake.

Braze: To join by brazing.

Brazing: The process of permanently joining metal parts by intense heat.

Breaker Strip: A strip of canvas placed between the tread and body of an outer tire casing to increase the wearing qualities.

Breather: An opening in the crankcase of a gas engine to permit pressure therein to remain equal during the movement of the pistons.

British Thermal Unit. The ordinary unit of heat. It is that quantity of heat required to raise the temperature of one pound of pure water one degree Fahrenheit at the temperature of greatest density of water.

Brougham Body: A closed-in automobile body having windows at the side doors, and in front, but with no extension of the roof over the front seat.

Brush Holder: In electrical machinery, an arrangement to hold one end of a connection flexible in contact with a moving part of the circuit.

B. T. U.: Abbreviation for *British Thermal Unit.*

Buckboard: A four-wheeled vehicle in which the body and springs are replaced by an elastic board or frame

Buckling: Irregularities in the shape of the plates of storage cells following a too rapid discharge.

Bumper: (1) A contrivance at the front of the car to minimize shock of collision; it consists of plungers working in tubes and gaining elasticity from springs. (2) A bar placed across the end of a car, usually the front end, to take the shock of collision and thus prevent damage to the car itself. A rubber or leather pad interposed between the axle and frame of a car.

Burner, "Torch" Igniter: A movable auxiliary vaporizer for starting the fire in steam automobile burners.

Bushing: A bearing lining. Usually made of anti-friction metal and capable of adjustment or renewal.

Bus-Pipe: A manifold pipe.

Butterfly Valve: A valve inserted in a pipe, usually circular and of nearly the same diameter as the pipe, designed to turn upon a spindle through its diameter and thus shut off or permit flow through the pipe. Usually employed for throttle valves and carbureter air valves.

Buzzer: (1) A name sometimes applied to the vibrator or trembler of a jump-spark ignition coil. (2) A device used in place of a horn, and consisting of a diaphragm which is made to vibrate rapidly by an electromagnet.

By-Pass: A small valve to provide a secondary passage for fluids passing through a system of piping.

C

C: Abbreviation for a centigrade degree of temperature.

Calcium Carbide: A compound of calcium and carbon used for the generation of acetylene by the application of water.

Calcium Chloride: A salt which dissolved in water is used as an anti-freezing solution.

Cam: A revolving disk, irregular in shape, fixed on a revolving shaft so as to impart to a rod or lever in contact with it an intermittent or variable motion.

Cam, Exhaust: A cam designed to operate the exhaust of an engine.

Cam, Ignition: A cam designed to operate the ignition mechanism. In magnetos it operates the make-and-break device.

Cam, Inlet: A cam designed to operate the inlet valve of an engine.

Camber: (1) The greatest depth of curvature of a surface. (2) The amount of bend in an axle designed to incline the wheels.

Camber of Spring: The maximum distance between the upper and lower parts of a spring under a given load.

Cambered Frame: A narrowing of the front of a motor car to permit of easier turning.

Cam Gear: The gear driving the camshaft of a gas engine. In a four-cycle engine this is the same as the two-speed gear.

Camshaft: A shaft by which the valve cams are rotated; also known as the *secondary shaft.*

Camshaft, Overhead: The camshaft carried along or above the cylinder heads, to operate overhead valves.

Camshaft Gears: The gears or train of gears by which the camshaft is driven from the crankshaft. Half-time gears, timing gears, distribution gears.

Canopy: An automobile top that can not be folded up.

Capacity of a Condenser: The quality of electricity or electrostatic charge. Of a storage battery, the amount of electricity which may be obtained by the discharge of a fully charged battery. Usually expressed in ampere hours.

Cape Hood: An automobile top which is capable of either being folded up or extended.

Car: A wheeled vehicle.

Carbide: See "Calcium Carbide".

Carbide Feed: A type of acetylene generator in which the calcium carbide is fed into the water.

Carbon Bridge: Formation of soot between points of spark plug.

Carbon Deposit: A deposit upon the interior of the combustion chamber of a gasoline engine composed of carbonaceous particles from the lubricating oil, too rich fuel mixture, or road dust.

Carbon Remover: A tool or solution for removing carbon deposits from the cylinder, piston, or spark plug of a gasoline engine.

Carbonization: The deposit of carbon.

Carbureter: An appliance for mixing an inflammable vapor with air. It allows air to be passed through or over a liquid fuel and to carry off a portion of its vapor mixed with the air, forming an explosive mixture.

Carbureter, Automatic: A carbureter so designed that either the air supply alone or both the air and gasoline supplies are regulated automatically.

Carbureter, Constant-Level: A carbureter the level of the gasoline in which is maintained automatically at a constant height. A float-feed carbureter.

Carbureter, Exhaust-Jacketed: A carbureter whose mixing chamber is heated by the circulation of exhaust gas.

Carbureter, Multiple-Jet: A carbureter having more that one spray nozzle or jet.

Carbureter, Water-Jacketed: A carbureter whose mixing chamber is heated by the circulation of water from the cooling system.

Carbureter Float: A buoyant part of the carbureter designed to float in the gasoline and connected to a valve controlling the flow from the fuel tank, designed to maintain automatically a constant level of the gasoline in the flow chamber.

Carbureter Float Chamber: A reservoir containing the float and in which a constant level of fuel is maintained.

Carbureter Jet: The opening through which liquid fuel is ejected in a spray from the standpipe of a carbureter nozzle.

Carbureter Needle Valve: A valve controlling the flow of fuel from the flow chamber to the standpipe.

Carbureter Nozzle: See "Carbureter Jet".

Carbureter Standpipe: A vertical pipe carrying the nozzle.

Carburetion: The process of mixing hydrocarbon particles with the air. The action in a carbureter.

Cardan Joint: A universal joint or Hooke's coupling.

Cardan Shaft: A shaft provided with a Cardan joint at each end.

Casing: The shoe or outer covering of a double-tube automobile tire.

Catalytic Ignition: See "Ignition,Catalytic".

Cell: One of the units of a voltaic battery.

Cell, Dry: See "Dry Cell".

Cell, Storage: See "Accumulator".

Cellular Radiator: A radiator in which the openings between the tubes are in the form of small cells. The same as a *honeycomb radiator*.

Cellular Tire: A cushion tire which is divided into compartments or cells.

Center of Gravity: That point in a body, which, if the body were suspended freely in equilibrium, would be the point of application of the resultant forces of gravity acting upon the body.

Center Control: The location of the gear-shift and emergency brake levers of a car in the center of a line parallel to the front of the front seat.

Centigrade Scale: The thermometer scale invented by Celsius. Used universally in scientific work.

Century. In automobiling, a hundred-mile run.

C. G. S. System: Abbreviation for centimeter-gram-second system of measurement; the standard system in scientific work.

Chain, Drive: A heavy chain by which the power from the motor may be transmitted to the rear wheels of an automobile.

Chain, Roller: A sprocket chain, the cross bars of whose links are rollers.

Chain, Silent: See "Silent Chain".

Chain, Tire: A small chain fastened about the tire to increase traction and prevent skidding.

Chain Wheel: A sprocket wheel for the transmission chains of a motor-driven vehicle.

Change-Speed Gear: See "Gear, Change-Speed".

Change-Speed Lever: See "Lever, Change-Speed".

Charge: The fuel mixture introduced into the cylinder of a gas engine. The act of storing up electric energy in an accumulator.

Charging: The passing of a current of electricity through a storage cell.

Charles' Law of Gases: See "Gases, Gay Lussac's Law of".

Chassis. The mechanical features of a motor car assembled, but without body, fenders, or other superstructure not essential to the operation of the car.

Chauffeur: In America this term means the paid driver or operator of a motor car. The literal translation from the French means stoker or fireman of a boiler.

Check, Steering: See "Steering Check".

Check Valve: An automatic or non-return valve used to control the admission of feed water in the boiler, etc.

Choke: The missing of explosions or poor explosions due to too rich mixture.

Circuit, Primary: See "Primary Circuit".

Circuit, Secondary: See "Secondary Circuit".

Circuit Breaker: A device installed in an electric circuit and intended to open the circuit automatically under predetermined conditions of current flow.

Circulating Pump: A pump which keeps a liquid flowing through a series of pipes which provides a return circuit. In a motor car, water and oil circulation is maintained by circulating pump.

Circulation Pump: A mechanically operated pump by which the circulation of water in the cooling system is maintained.

Circulating System: The method or series of pipes through which a continuous flow of water or oil is maintained and in which the liquid is sent through the system over and over.

Clash Gear: A sliding change-speed gear.

Clearance: (1) The distance between the road surface and the lowest part of the under-body of an automobile. (2) The space between the piston of an engine when at the extremity of its stroke, and the head of the cylinder.

Clearance, Valve: See "Valve Clearance".

Clearance Space: The space left between the end of the cylinder and the piston plus the volume of the ports between the valves and the cylinder.

Clevis: The fork on the end of a rod.

Clevis Pin: The pin passing through the ends of a clevis and through the rod to which the clevis is joined.

Clincher Rim: A wheel rim having a turned-in edge on each side, forming channels. Into this the edge or flange of the tire fits, the air pressure within locking the tire and rim together.

Clincher Tire: A pneumatic tire design to fit on a clincher rim.

Clutch: A device for engaging or disconnecting two pieces of shafting so that they revolve together or run free as desired.

Clutch Cone: A clutch whose engaging surfaces consist of the outer surface of the frustrum of one cone and the inner surface of the frustrum of another.

Clutch, Contracting-Band: A clutch consisting of a drum and band, the latter contracting upon the former.

Clutch, Dry-Plate: A clutch whose friction surfaces are metal plates, not lubricated.

Clutch, Expanding-Band: A clutch consisting of a drum and band, the latter expanding within the former.

Clutch, Jaw: A clutch whose members lock end to end by projections or jaws in one entering corresponding depressions in the other.

Clutch, Multiple-Disk: A clutch whose friction surfaces are metal plates or disks, alternate disks being attached to one member and the rest to the other member of the drive.

Clutch Brake: A device designed to stop automatically the rotation of the driven member of a clutch after disengagement from the driving member.

Clutch Lining: The wearing surface of a clutch. This may be easily removed and replaced when worn.

Clutch Pedal: The pedal by which the clutch may be disengaged, engagement being obtained automatically by means of a spring.

Clutch Spring: A spring arranged to either hold a clutch out of gear or throw it into gear.

Coasting: The movement of the car without constant applications of the motive power, as in running downhill with the aid of gravity or on the level, through the momentum obtained by previous power applications.

Cock, Priming: A small cock, usually operated by a lever, for admitting gasoline to the carbureter to start its action.

Coil, Induction: See "Spark Coil".

Coil, Non-Vibrator: A coil so designed that it will supply a sufficient spark for the ignition with one make and break of the primary circuit.

Coil, Primary: See "Primary Coil".

Coil, Secondary: See "Secondary Spark Coil".

Coil, Spark: See "Spark Coil".

Coil, Vibrator: A spark coil with which is incorporated an electromagnetic vibrator to make and break the primary circuit.

Coil Vaporizer: An auxiliary vaporizer to assist in starting a steam boiler. It is a coil of tubing into which liquid gasoline is admitted and burned to start the generation of gas in the main burner.

Cold Test: The temperature in degrees Fahrenheit at which a lubricant passes from the fluid to the solid state.

Combustion Chamber: That part of an explosive motor in which the gases are compressed and then fired, usually by an electric spark.

Combustion Space: See "Clearance" and "Clearance Space".

Commercial Car: A motor-driven vehicle for commercial use, such as transporting passengers or freight.

Commutator: In the ignition system of an explosive motor, the commutator is a device to automatically complete the circuit of each of a number of cylinders in succession.

Commutator of Dynamo or Motor: That part of a dynamo which is designed to cause the alternating current produced in the armature to flow in one direction in the external circuit; in a motor, to change the direct current in the external circuit into alternating current.

Compensating Carbureter: An automatic attachment to a carbureter controlling either air or fuel admission, or both, so that the proportion of one to the other is always maintained under any vibration of power required.

Compensating Gear: See "Differential Gear".

Compensating Joint: See "Universal Joint".

Compound Engine: A multiple-expansion steam engine in which the steam is expanded in two stages, first in the high-pressure cylinder and then in the low-pressure cylinder.

Compression: (1) That part of the cycle of a gas engine in which the charge is compressed before ignition; in a steam engine it is the phase of the cycle in which the pressure is increased, due to compression of the exhaust steam behind the piston. (2) The greatest pressure exerted on the gas in the compression chamber.

Compression Chamber: The clearance volume above the piston in a gas engine; also called "Compression Space".

Compression Cock: See "Compression-Relief Cock".

Compression Line: The line on an indicator diagram corresponding to the phase of the cycle in which the gas is compressed.

Compression-Relief Cock: A small cock by which the compression chamber of an internal-combustion motor may be opened to the air and thus allow the compression in the cylinder to be relieved to facilitate turning by hand, or *cranking*.

Compression Space: See "Compression Chamber".

Compression Tester: A small pressure gage by which the degree of compression of the mixture in a gas-engine cylinder may be tested.

Compressor, Air: See "Air Compressor".

Condenser: (1) In a steam motor, an apparatus in which the exhaust steam is converted back into water. (2) A device for increasing the electric capacity of a circuit. Used in an ignition circuit to increase the strength of the spark.

Cone Bearing: A shaft bearing in which the shaft is turned to a taper and the journal turned to a conical or taper form.

Cone Clutch: A friction clutch in which there are two cones, one fitting within the other.

Connecting Rods: The part of an engine connecting the piston to the crank, and by means of which a reciprocating motion of the piston is converted into the rotary motion of the crank.

Constricting Band Brake: See "Brake, Constricting Band".

Constricting Clutch: A friction clutch in which a band is tightened around a drum to engage it.

Contact Breaker: A device on some forms of gasoline motors having an induction coil of the single jump-spark type, to open and close the electric circuit of the battery and coil at the proper time for the passage of the arc or spark at the points of the spark plug.

Contact Maker: See "Contact Breaker".

Continental Drive: Double-chain drive.

Control: The levers, pedals, etc., in general with the speed and direction of a car is regulated by the driver. In speaking of right, left, or center control, the gearshift and emergency brake levers only are meant.

Control, Spark: Method of controlling the power of an engine by varying the point in the stroke at which ignition takes place.

Control, Throttle: Method of governing the power of the engine by altering the area of the passage leading to the admission valve so that the amount of the fuel introduced into the cylinder is varied.

Controller, Electric: Apparatus for securing various combinations of storage cells and of motors so as to vary the speed of the car at will.

Converter: A device for changing alternating current into direct current for charging storage batteries, etc. Converters may be any of three kinds: rotary, electrolytic, or mercury-vapor. The mercury-vapor converter is most widely used.

Convertible Body: An automobile body which may be used in two or more ways, usually as an open or closed carriage, or in which several seats may be concealed, and raised to increase the seating capacity.

Cooling Fan: Fan used in automobiles to increase the current of air circulating around the cylinders, or through the radiator.

Cooling System: The parts of a gas engine or motor car by which the heat is generated in the cylinder by the combustion of the fuel mixture. See "Water Cooling" and "Air Cooling".

Cork Inserts: Pieces of cork inserted in friction surfaces of clutches or brakes to give softer action.

Cotter Pin: A split metal pin designed to pass through holes in a bolt and nut to hold the former in place.

Coulomb: The unit of measure of electrical quantity. Sometimes called "Ampere Second". It is equivalent to the product of the current in amperes by the number of seconds current has been flowing.

Counterbalance: Weights attached to a moving part to balance that part.

Countershaft: An intermediate or secondary shaft in the power-transmission system.

Coupé: An enclosed body seating one or two passengers and the driver, all within.

Coupling, Flexible: See "Universal Joint".

Cowl: That portion of the body of the car which forms a hood over the instrument board or dash.

Cowl Tank: A fuel tank carried under the cowl and immediately in front of the dash.

Crank: A lever designed to convert reciprocating motion into rotating motion or *vice versa;* usually in the form of a lever formed at an angle with the shaft, and connected with piston by means of connecting rod.

Crank, Starting: A handle made to fit the projecting end of the crankshaft of a gas engine, so that the engine may be started revolving by hand.

Crankcase: The casing surrounding the crank end of the engine.

Crankcase Explosion: Explosion of unburned gases in the crankcase.

Crank Chamber: The enclosed space of small engines in which the crank works.

Cranking: The act of rotating the motor by means of a handle in order to start it. Turning the flywheel over a few times causes the engine to take up its cycle, and after an explosion it continues to operate.

Crankpin: The pin by which the connecting rod is attached to the crank.

Crankshaft: The main shaft of an engine.

Crankshaft, Offset: A crankshaft whose center line is not in the same plane as the axis of its cylinders.

Creeping of Pneumatic Tires: The tendency of pneumatic tires to push forward from the ground, and thus around the rim, in the effort to relieve and distribute the pressure.

Cross Member: A structural member of the frame uniting the side members.

Crypto Gear: See "Planetary Gear".

Crystallization. The rearrangement of the molecules of metal into a crystalline form under continued shocks. This is often the cause of the breaking of the axles and springs of a motor car.

Cup, Priming: A small cup-shaped device provided with a cock, by which a small quantity of gasoline can be introduced into the cylinder of a gasoline engine.

Current: The rate of flow of electricity; the quantity of electricity which passes per second through a conductor or circuit.

Current Breaker: See "Contact Breaker".

Current Indicator: A device to indicate the direction of current flow in a circuit; a polarity indicator.

Current Rectifier: A device for converting alternating current into direct current. See "Converter".

Cushion Tire: See "Tire, Cushion".

Cut-Off, Gas Engine: That point in the cycle of an internal-combustion engine at which the admission of the mixture is discontinued by the closing of the admission valve.

Cut-Off, Steam Engine: That point in the cycle of a steam engine, or that point on an indicator diagram, at which the admission of steam is discontinued by the closing of the admission valve.

Cut-Out, Automatic: A device in a battery charging circuit designed to disconnect the battery from the circuit when the current is not of the proper voltage.

Cut-Out, Muffler: A device by which the engine is made to exhaust into the air instead of into the muffler.

Cut-Out Pedal: Pedal by means of which the engine is made to exhaust into the air instead of into the muffler.

Cycle: A complete series of operations beginning with the drawing in of the working gas, and ending after the discharge of the spent gas.

Cycle, Beau de Rochas: See "Beau de Rochas Cycle".

Cylinder: A part of a reciprocating engine consisting of a cylindrical chamber in which a gas is allowed to expand and move a piston connected to a crank.

Cylinder Bore: See "Bore".

Cylinder Cock: A small cock used to allow the condensed water to be drained away from the cylinder of a steam engine, usually called a *drain cock*.

Cylinder Head: That portion of a cylinder which closes one end.

Cylinder Jacket: See "Jacket, Water".

Cylinder Oil: Lubricant particularly adapted to the lubrication of cylinder walls and pistons of engines.

D

Dash: The upright partition of a car in front of the front seat and just behind the bonnet,

Dash Adjustment: Connections by which a motor auxiliary may be adjusted by a handle on the dash. Usually applied to carbureter adjustments.

Dash Coil: An induction coil for jump-spark ignition, having an element for each cylinder, with dash connections to the commutator on the engine or camshaft.

Dash Gage: A steam, water, oil, or electric gage placed upon the dash of the car.

Day Type of Engine: The two-cycle internal-combustion engine with an air-tight crankcase.

Dead Axle: See "Axle, Dead".

Dead Center: The position of the crank and connecting rod in which they are in the same straight line. There are two positions, and in these positions no rotation of the crankshaft is caused by pressure on the piston.

Decarbonizer: See "Carbon Remover".

Deflate: Reduction of pressure of air in a pneumatic tire.

Deflector: In a two-cycle engine, the curved plate on the piston head designed to cause the incoming charge to force out the exhaust gases and thus assist in scavenging.

Deflocculated Graphite: Graphite so finely divided that it remains in suspension in a liquid.

Demountable Rim: A rim upon which a spare tire may be mounted and carried, and so arranged that it may be easily and quickly taken off or put on the wheel.

Denatured Alcohol: See "Alcohol, Denatured".

Densimeter: See "Hydrometer".

Depolarizer: Material surrounding the negative element of a primary cell to absorb the gas which would otherwise cause polarizing.

Detachable Body: A body which may be detached from and placed upon the chassis.

Detachable Rim: See "Demountable Rim".

Diagram Indicator: See "Indicator Card".

Diagram, Jeantaud: A diagrammatic representation of the running gear of an automobile, showing it turning corners of various radii for the purpose of determining the front-axle and steering connections.

Diesel Gas Engine: Four-cycle internal-combustion engine in which the explosion of the charge is accomplished entirely by the temperature produced by the high compression of the mixture.

Differential, Bevel-Gear: A balance gear in which the equalizing action is obtained by means of bevel gears.

Differential, Spur-Gear: A differential gear in which the equalizing action is obtained by spur gears.

Differential Brake: See "Brake, Differential".

Differential Case: See "Differential Housing".

Differential Gear: A mechanism to permit driving the wheels and yet allow them to turn a corner without slipping. An arrangement such that the driving wheels may turn independently of each other on a divided axle, both wheels being under the control of the driving mechanism. Sometimes called *balance, compensating,* or *equalizing gear.*

Differential Housing: The case that encloses the differential gear.

Differential Lock: A device which prevents the operation of the differential gear, so that the wheels turn as if they were on a solid shaft.

Dimmer: An arrangement for lowering the intensity of, or reducing the glare from headlights.

Direct Current: A current which does not change its direction of flow, as the current from a battery or a direct-current generator. Distinguished from an alternating current, which reverses its direction many times a minute.

Direct Drive: Transmission of power from engine to the final driving mechanism at crankshaft speed.

Discharge: In a storage battery, the passage of a current of electricity stored therein. In the ignition circuit, the flow of high-tension current at the spark gap.

Disk Clutch: A clutch in which the power is transmitted by a number of thin plates pressed face to face.

Distance Rod: See "Radius Rod".

Distribution Shaft: See "Camshaft".

Distributor: That part of the ignition system which directs the high-tension current, to the respective spark plugs in the proper firing order.

Double Ignition: A method of ignition which comprises two separate systems, either of which may be used independently of the other, or both together as desired. Usually distinguished by two current sources and two sets of plugs.

Drag: That action of a clutch or brake which does not completely release.

Drag Link: That rod in a steering gear which forms the connection between the mechanism mounted on the frame and the axle stub, and transmits the movements of steering from steering post to wheels.

Drive Shaft: The shaft transmitting the motion from the change gears to the driving axle; the torsion rod.

Driving Axle: The axle of a motor car through which the power is transmitted to the wheels.

Driving Wheel: The wheel to which or by which the motion is transmitted.

Dry Battery: A battery of one or more dry cells.

Dry Cell: A primary voltaic cell in which a moist material is used in place of the ordinary fluid electrolyte.

Dual Ignition: An ignition system comprising two sources of current and one set of spark plugs.

Dust Cap: A metal cap to be screwed over a tire valve to protect the latter from dust and water.

Dynamo: The name frequently applied to a dynamo-electric machine used as a generator. Strictly, the term *dynamo* should be applied to both motor and generator.

Dynamometer: The form of equalizing gear attached to a source of power or a piece of machinery to ascertain the power necessary to operate the machinery at a given rate of speed and under a given load.

E

Earth: See "Ground".

Economizer, Gas: An appliance to be attached to a float-feed carbureter to improve the mixture by automatically governing the amount of air in the float chamber.

Eccentric: A disk mounted off-center on a shaft to convert rotary into reciprocating motion.

Economy, Fuel: The fuel economy of a motor is the relation between the heat units

in the fuel used in the motor and the work or energy given out by the motor.

Efficiency: The proportion of power obtained from a mechanism as compared with that put into it.

Efficiency of a Motor: The efficiency of a gasoline motor is the relation between the heat units consumed by the motor and the work of energy in foot-pounds given out by it. Electrical efficiency of a motor is the relation between the electrical energy put into the motor and the mechanical energy given out by it.

Ejector: An apparatus by which a jet of steam propels a stream of water in almost the same way as an injector, except that the ejector delivers it into a vessel having but little pressure in it.

Electric Generator: A dynamo-electric machine in which mechanical energy is transformed into electrical energy; usually called *dynamo*.

Electric Horn: An automobile horn electrically operated.

Electric Motor: A dynamo-electric machine in which electrical energy is transformed into mechanical energy.

Electric Vehicle: An automobile propelled by an electric motor, for which current is supplied by a storage battery carried in the vehicle.

Electrolyte: A compound which can be decomposed by electric current. In referring to storage batteries, the term electrolyte means the solution of sulphuric acid in water in which the positive and negative plates are immersed.

Electromagnet: A temporary magnet which obtains its magnetic properties by the action of an electric current around it and which is a magnet only as long as such current is flowing.

Electromotive Force: A tendency to cause a current of electricity to flow; usually synonymous with *potential, difference of potential, voltage,* etc.

Element: The dissimilar substances in a battery between which an electromotive force is set up, as the plates of a storage battery.

Emergency Brake: A brake to be applied when a quick stop is necessary; usually operated by a pedal or lever.

En Bloc: That method of casting the cylinders of a gasoline engine in which all the cylinders are made as a single casting. Block casting; monoblock casting.

End Play: Motion of a shaft along its axis.

Engine, Alcohol: An internal-combustion engine in which a mixture of alcohol and air is used as fuel.

Engine, Gasoline: An internal-combustion motor in which a mixture of gasoline and air is used as fuel.

Engine, Kerosene: An internal-combustion engine in which a mixture of kerosene and air is used as fuel.

Engine, Steam: An engine in which the energy in steam is used to do work by moving the piston in a cylinder.

Engine Primer: A small pump to force fuel into the carbureter.

Engine Starter: An apparatus by which a gasoline engine may be started in its cycle of operations without use of the starting crank. It belongs usually to one of four classes: (1) Mechanical or spring actuated, such as a coil spring wound up by the running of the engine or a strap around the flywheel; (2) fluid pressure, such as compressed air or exhaust gases induced into the cylinder to drive the piston through one cycle; (3) the electric system, in which a small motor is used to turn the engine over; (4) combinations of these.

Epicyclic Gear: See "Planetary Gear".

Equalizing Gear: See "Differential Gear".

Exhaust: The gases emitted from a cylinder after they have expanded and given up their energy to the piston; the emission of the exhaust gases.

Exhaust, Auxiliary: See "Auxiliary Exhaust".

Exhaust Horn: An automobile horn in which the sound is produced by the exhaust gases.

Exhaust Lap: The extension of the inside edges of a slide valve to give earlier closing of the exhaust. Also called *inside lap*.

Exhaust Manifold: A large pipe into which the exhaust passages from all the cylinders open.

Exhaust Port: The opening through which the exhaust gases are permitted to escape from the cylinder.

Exhaust Steam: Steam which has given up its energy in the cylinder and is allowed to escape.

Exhaust Stroke: The stroke of an internal-combustion motor during which the burned gases are expelled from the cylinder.

Exhaust Valve: A valve in the cylinder of an engine through which the exhaust gases are expelled.

Expanding Clutch: A clutch in which a split pulley is expanded to press on the inner circumference of a ring which surrounds it, and thus transmits motion to the ring.

Expansion, Gas Engine: That part of the cycle of a gas engine immediately after ignition, in which the gas expands and drives the piston forward.

Expansion, Steam Engine: That portion of the stroke of the steam engine in which the steam is cut off by the valves and continues to perform work on the piston, increasing in volume and decreasing in pressure.

Explosive Motor: See "Internal-Combustion Motor".

F

Fan, Cooling: A mechanically operated fan for producing a current of air for cooling the radiator or cylinder of a gas engine.

Fan, Radiator: A mechanically operated rotary fan used to induce the flow of air through the radiator to facilitate the cooling of the water.

Fan Belt: The belt which drives the cooling fan.

Fan Pulley: A pulley permanently attached to the fan and over which the fan belt runs to drive it.

Fat Spark: A short, thick, ignition spark.

Feed Pump: A pump by which water is delivered from the tank to the boiler of a steam car.

Feed Regulator: A device to maintain a uniform water level in a steam boiler by controlling the speed of the feed pump.

Feed-Water Heater: An apparatus for heating the boiler-feed water, either by means of a jet of steam or steam-heated coils.

Fender: A mud guard or shield over the wheels of a car.

Field, Magnetic: Space in the neighborhood of the poles of a magnet in which the magnetism exerts influence. Field also refers to the coils which produce the magnetism in an electromagnet.

Fierce Clutch: A clutch which cannot be engaged easily. A grabbing clutch.

Filler Board: Woodwork shaped to fill the space between the lower edge of the windshield and the dash.

Fin: Projections cast on the cylinders of a gas engine to assist in cooling.

Final Drive: That part of a car by which the driving effort is transmitted from the parts of the transmission carried on the frame to the transmission parts on the rear axle. The propeller shaft in a shaft-drive car.

Fire Test: A test of a lubricant to determine the temperature at which it will burn.

Firing: (1) Ignition of the charge in a gas engine. (2) The act of furnishing fuel under the boiler of a steam engine.

First Speed: That combination of transmission gears which gives the lowest gear ration forward. Slow speed; low speed.

Flash Boiler: A boiler arranged to generate highly superheated steam almost instantaneously, by allowing water to come in contact with very hot metal surfaces.

Flash Generator: See "Flash Boiler".

Flash Point: The temperature at which an oil will give off a vapor that will ignite when a flame comes in contact with it.

Flash Test: A test to determine the flash point of oils.

Flexibility: In an engine the ability to do useful work through a range of speeds.

Flexible Coupling: See "Universal Joint".

Flexible Shaft: A pliant shaft which will transmit considerable power when revolving.

Flexible Tubing: A tube for the conduction of liquids or gases, which may be bent at a small radius without leaking.

Float Carbureter: A carbureter for gasoline engines in which a float of cork or hollow metal controls the height of the liquid in the atomizing nozzle. Sometimes called *float-feed carbureter*.

Float Valve: An automatic valve by which the admission of a liquid into a tank is controlled through a lever attached to a hollow sphere which floats on the surface of the liquid and opens or closes the valve according as it is high or low.

Floating Axle: See "Axle, Floating".

Floating the Battery on the Line: Charging the battery while it is giving out current.

Flooding: Excessive escape of fuel in a carbureter from the spraying nozzle.

Flushing Pin: In a float-feed carbureter, a pin arranged to depress the float in priming. Also called *primer* and *tickler*.

Flywheel: A wheel upon the shaft of an engine which, by virtue of its moving mass, stores up the energy of the gas transmitted to the flywheel during the impulse stroke and delivers it during the rest of the cycle, thus producing a fairly constant torque.

Flywheel Marking: Marks on the face of a flywheel to indicate the time of valve opening and closing and thus assist in valve setting.

Foaming: See "Priming".

Fore Carriage: A self-propelled vehicle in which the motor is carried on the forward trucks, and propelling and steering is done with the forward trucks.

Fore-Door Body: An automobile body having doors in the forward compartment.

Four-Cycle or Four-Stroke Cycle: The cycle of operations in gas engines occupying two complete revolutions or four strokes.

Four-Wheel Drive: Transmission of driving effort to all four wheels.

Fourth Speed: That combination of transmission gears which gives the fourth from the lowest gear ratio forward. Usually the highest speed.

Frame: The main structural part of a chassis. It is carried upon the axles by the springs and carries the different elements of the car.

Frame Hangers: See "Body Hangers".

Free Wheel: A wheel so arranged that it can rotate more rapidly than the mechanism which drives it.

Friction: The resistance existing between two bodies in contact which tends to prevent their motion on each other.

Friction Clutch: A device for coupling and disengaging two pieces of shafting while in motion, by the friction of cones or plates on one another.

Friction Disk: The thin plate used in a disk or friction clutch. See "Disk Clutch".

Friction Drive: A method of transmitting power or motion by frictional contact.

Fuel: A combustible substance by whose combustion power is produced. Gasoline and kerosene are the chief automobile fuels.

Fuel Economy. See "Economy, Fuel".

Fuel Feed, Gravity: See "Gravity Fuel Feed".

Fuel Feed, Pressure: See "Lubrication, Force-Feed."

Fuel Feed, Vacuum. See "Vacuum Fuel Feed".

Fuel-Feed Regulator: A device in the fuel system of steam motor by which the rate of flow of fuel to the burner is automatically regulated.

Fuel Level: The height of the top of the fuel in the float chamber of a carbureter.

Fuel-Level Indicator: An instrument either permanently connected to the fuel tank or which may be inserted thereon to indicate the quantity of fuel in the tank.

Fuel Tank, Auxiliary: A tank designed to hold a supply of fuel in addition to that carried in the main shaft.

Fuse: A length of wire in an electric circuit designed to melt and open the circuit when excess current flows through it and thus prevent damage to other portions of the circuit.

Fusible Plug: A hollow plug filled with an alloy which melts at a point slightly above the temperature of the steam in a boiler, as when the water runs low, thus putting out the fire and preventing the burning out of the boiler.

G

Gage: (1) Strictly speaking, a measure of, or instrument for determining dimensions or capacity. Practically, the term refers to an instrument for indicating the pressure or level of liquids, etc. (2) The distance between the forward or rear wheels measured at the points of contact of the tires on the road. Tread; track.

Gage Cock: A small cock by which a pipe leading to a gage may be opened or closed.

Gage Lamp: Lamp, usually electric, placed above or near the gages to enable them to be read at night.

Gage, Oil: See "Oil Gage".

Gage, Tire: See "Tire-Pressure Gage".

Gap: In automobiles, the spark gap.

Garage: A building for storing and caring for automobiles.

Garage, Portable: A garage which may be moved from one place to another either as a whole or in sections.

Gas: Matter in a fluid form which is elastic and has a tendency to expand indefinitely with reduction in pressure.

Gas Economizer: See "Economizer".

Gas Engine: An internal-combustion motor in which a mixture of gas and air is used as fuel. The term is also applied to the gasoline engine.

Gas Engine, Otto: A four-stroke cycle engine developed by Otto and using the hot-tube method of ignition.

Gas Generator: An apparatus in which a gas is generated for any use.

Gas Lamp: See "Acetylene Lamp".

Gases, Boyle's Law of: See "Boyle's Law of Gases".

Gases, Gay Lussac's Law of: Called *Charles's Law* and the *Second Law of Gases*. Law defining the physical properties of gases at constantly maintained pressure. It states that at constant pressure the volume of gas varies with the temperature, the increase being in proportion to the change of temperature and volume of the gas.

Gasket: A thin sheet of packing material or metal used in making joints, piping, etc.

Gasoline: A highly volatile fluid petroleum distillate; a mixture of fluid hydrocarbons.

Gasoline-Electric Transmission: A system of propulsion in which a gasoline engine drives an electric generator, and the power is transmitted electrically to motors which drive the wheels.

Gasoline Engine: An internal-combustion motor in which a mixture of gasoline and air is used as a fuel.

Gasoline Primer: The valve on the carbureter of a gasoline engine by which the action of the engine can be started.

Gasoline-Tank Gage: A fuel-lever indicator for gasoline.

Gasoline Tester: A hydrometer graduated to indicate the specific gravity of gasoline, usually in degrees Baumé.

Gate: A plate which guides the gearshift lever in making speed changes.

Gather: Convergence of the forward portions of the front wheels. Toeing in.

Gay Lussac's Law of Gases: See "Gases, Gay Lussac's Law of".

Gear, Balance: See "Differential Gear".

Gear, Bevel: See "Bevel Gear".

Gear, Change-Speed: An arrangement of gear wheels which transmits the power of the motor to the differential gear at variable speeds independently of the motor speed.

Gear, Differential: See "Differential".

Gear, Fiber: A gear cut from a vulcanized fiber blank.

Gear, Helical: A gear whose teeth are not parallel to the axis of the cylinders.

Gear, Internal: A gear whose teeth project inward toward the center from the circumference of gear wheel.

Gear, Planetary: See "Planetary Gears".

Gear, Progressive: See "Progressive Change-Speed Gears".

Gear, Rawhide: A gear cut from a blank made up of compressed rawhide.

Gear, Selective: See "Selective Change-Speed Gears".

Gear, Timing: See "Timing Gears".

Gear, Worm: A helical gear designed for transmitting motion at angles, usually at right angles and with a comparatively great speed reduction.

Gearbox: The case covering the change-speed gears.

Gear Shifting: Varying the speed ration between motor and rear wheels by operating the change-speed gears.

Gear-Shift Lever: A lever by which the change-speed gears are shifted.

Geared-Up Speed: A speed obtained by an arrangement of gears in the gearset such that the propeller shaft rotates more rapidly than the crankshaft.

Gearset: See "Gear, Change-Speed".

Generator, Acetylene: See "Acetylene Generator".

Generator, Electric: See "Electric Generator".

Generator, Steam: A steam boiler.

Generator Tubing: Tubing by which acetylene is conducted from the generator to the lamp.

Gimbal Joint: A form of universal joint.

Gong: A loud, clear sounding bell, usually operated either electrically or by foot power.

Governor: A device for automatically regulating the speed of an engine.

Governor, Dynamo: A method of automatic control of the generator (usually an ignition generator, in automobile work) by which its speed is maintained approximately constant.

Governor, Hydraulic: A governor applied to engines cooled by a pump circulation of water in such a way that the throttle opening is controlled by the pressure of the water.

Governor, Spark: A method of automatically controlling the speed of the engine by varying the time of ignition. See "Governor".

Grabbing Clutch: See "Fierce Clutch".

Gradometer: An instrument for indicating the degree of the gradient or the per cent of the grade. It consists of a level with a graduated scale.

Graphite: One of the forms in which carbon occurs in matter. Also known as *black lead*

and *plumbago*. Used as a lubricant in powdered or flake form in the cylinders of explosive engines.

Gravity-Feed Oiling System: See "Lubrication, Gravity".

Gravity Fuel Feed: Supply of fuel to the carbureter from the tank by force of gravity.

Grease and Oil Gun: A syringe by means of which grease or oil may be introduced into the bearings of the machinery.

Grease Cup: A device designed to feed grease to a bearing by the compression of a hand screw.

Grid: A lead plate formed in the shape of a gridiron to sustain and act as a conductor of electricity for the active material in a storage battery.

Grinding Valves: See "Valve Grinding".

Gripping Clutch: See "Fierce Clutch".

Ground: An electric connection with the earth, or to the framework of a machine.

H

Half-Motion Shaft: See "Half-Time Shaft".

Half-Time Gear: See "Timing Gears".

Half-Time Shaft: The cam shaft of a four-cycle gas engine. It revolves at one-half the speed of the crankshaft.

Hammer Break: A make-and-break ignition system in which the spark is produced when the moving terminal strikes the stationary terminal like a hammer.

Header: A pipe from which two or more pipes branch. Manifold.

Heater, Automobile: A device for warming the interior of an automobile, usually electric, or by means of exhaust gases or jacket water.

High Gear: That combination of change-speed gears which gives the highest speed.

High-Tension Current: A current of high voltage, as the current induced in the secondary circuit of a spark coil.

High-Tension Ignition: Ignition by means of high-tension current.

High-Tension Magneto: A magneto which delivers high-tension current.

Honeycomb Radiator: A radiator consisting of many very thin tubes, giving it a cellular appearance.

Hood: (1) That part of the automobile body which covers the frame in front of the dash. The engine is usually under the hood. (2) The removable covering for the motor.

Hooke's Coupler: See "Universal Joint".

Horizontal Motor: A motor the center line of whose cylinder lies in a horizontal plane.

Horn, Automobile: A whistle or horn for giving warning of the approach of the automobile.

Horsepower: The rate of work or energy expended in a given time by a motor. One horsepower is the rate or energy expended in raising a weight of 350 pounds one foot in one second, or raising 33,000 pounds one foot in one minute.

Horsepower, Brake: The power delivered at the flywheel of an internal combustion engine as ascertained by a brake test.

Horsepower, Rated: The calculated power which may be expected to be delivered by a motor. In America the term usually refers to the horsepower as calculated by the S.A.E. formula.

Hot-Air Intake: The pipe or opening conveying heated air to the carburetor.

Hot-Head Ignition: The method of igniting the charge in a gas-engine cylinder by maintaining the head of the combustion chamber at a high temperature from the internal heat of combustion, as in the Diesel engine.

Hot-Tube Ignition: An ignition device formerly used for gas engines in which a closed metal tube is heated red-hot by a Bunsen flame. When the compressed gases in the cylinder are allowed to come in contact with this, ignition takes place.

Housing: A metallic covering for moving parts.

H.P.: (1) Abbreviation for *horsepower*. (2) Abbreviation for *high pressure*.

Hub Cap: A metal cap placed over the outer end of a wheel hub.

Hydrocarbons: Chemical combinations of carbon and hydroger in varied proportions, usually distillates of petroleum, such as gasoline, kerosene, etc.

Hydrometer: An instrument by which the specific gravity or density of liquids may be ascertained.

Hydrometer Scale, Baumé's: An arbitrary measure of specific gravity.

I

I-Beam: Sometimes called *I-Section*. A structural piece having a cross section resembling the letter I. I-Beam front axle.

Igniter: An insulated contact plug without sparking points, used in make-and-break ignition with low-tension magneto.

Igniter, High-Speed: An igniter having a short spark coil for high-speed engines.

Igniter, Jump-Spark: A system of ignition in which is used a current of high pressure, which will jump across a gap in the high-pressure circuit, causing a spark at the gap.

Igniter, Lead of: Amount by which the ignition is advanced. See "Advanced Ignition".

Igniter, Primary: The apparatus in a primary circuit for making and breaking the circuit.

Igniter Spring: A spring to quickly break the circuit of a primary igniter.

Ignition, Advancing: See "Advanced Ignition".

Ignition, Battery: A system which gets its supply of current from a storage battery or dry cells. This system usually consists of a battery, a step-up coil, and a distributor for sending the current to the different spark plugs.

Ignition, Catalytic: Method of ignition for explosive motors based on the property of some metals, particularly spongy platinum, of becoming incandescent when in contact with coal gas or carbonized air.

Ignition, Double: See "Double Ignition".

Ignition, Dual: See "Dual Ignition".

Ignition, Fixed: Ignition in which the spark occurs at a given point in the cycle and cannot be changed from that point at the will of the operator except by retiming the ignition system. Fixed spark.

Ignition, Generator: Ignition current which is furnished by a combination lighting generator and magneto. The generator is

fitted with an interrupter and distributor. Sometimes refers to system in which a generator charges a battery and the latter furnishes the ignition current in connection with a coil and distributor.

Ignition, High-Tension: Sometimes called jump-spark. Ignition which is effected by means of a high-tension or high-voltage current which is necessary to jump a gap in the spark plug.

Ignition, Hot-Head: See "Hot-Head Ignition".

Ignition, Jump-Spark: See "Ignition, High-Tension".

Ignition, Low-Tension: See "Ignition, Make-and-Break".

Ignition, Make-and-Break: A system in which the spark is produced by the breaking or interruption of a circuit, the break occurring in the combustion space of the cylinder. The current used is of low-voltage, hence the synonym, low-tension ignition.

Ignition, Magneto: Ignition produced by an electric generator, called a magneto, which is operated by the gas engine for which it furnishes current. Dynamo ignition. Generator ignition.

Ignition, Master Vibrator: A system which uses as many non-vibrator coils as there are cylinders, and one additional coil, called the master vibrator, for interrupting the primary circuit for all coils. The master vibrator also is used with vibrator coils in which the vibrators are short-circuited.

Ignition, Premature: Ignition occurring so far before the top dead center mark that the explosion occurs before the piston has reached upper dead center.

Ignition, Primary: An ignition system in which a low-tension current flows through a primary coil, the circuit being mechanically opened, allowing a high-tension spark to jump across the gap. See "Primary Coil".

Ignition, Retarding: Setting the spark of an internal-combustion motor so that the ignition will occur at a later part of the stroke.

Ignition, Self: Explosion of the combustible charge by heat other than that produced by the spark. Incandescent carbon will cause this. Motor overheating because of lack of water is another cause.

Ignition, Single: A system using but one source of current.

Ignition, Synchronized: Ignition by means of which the timing in each cylinder of a multicylinder engine is the same. In synchronized ignition the spark occurs at the same point in the cycle in each cylinder. This type of ignition is obtained with a magneto and is lacking in a multi-coil system using vibrator coils.

Ignition, Timing of: The adjustment of the ignition system so that ignition will take place at the desired part of the cycle.

Ignition, Two-Independent: See "Ignition, Double".

Ignition, Two-Point: A system comprising two ignition sources, or a double-distributor magneto, and two sets of spark plugs, both of which spark at the same time.

Ignition Distributor: See "Distributor."

Ignition Switch: A control or switch for turning the ignition current on and off voluntarily

I. H. P.: Abbreviation for *indicated horsepower.*

Indicated Horsepower: (1) The horsepower developed by the fuel on the pistons, in contradistinction to brake horsepower. See "Horsepower, Brake". (2) The horsepower of an engine as ascertained from an indicator diagram.

Indicator: An instrument by which the working gas in an engine records its working pressure.

Indicator Card: A figure drawn by means of an indicator by the working gas in an engine. Also called *indicator diagram.*

Induction Stroke: The downstroke of a piston which causes a charge of mixture to be drawn into the cylinder.

Inflammation: The act or period of combustion of the mixture in the cylinder.

Inflate: To increase the pressure within a tire by forcing air into it.

Inflator, Mechanical Tire: A small power-driven air-pump for inflating the tire; either driven by gearing, chain, or belt from the engine shaft, or by friction from the flywheel.

Inherent Regulation: Expression applied to electric generators which use no outside means of regulating the output, the regulation being affected by various windings of the armature and fields.

Initial Air Inlet: See "Primary Air Inlet".

Initial Pressure: Pressure in a cylinder after the charge has been drawn in but not compressed.

Injector: A boiler-feeding device in which the momentum of a steam jet, directed by a series of conical nozzles, carries a stream of water into the boiler, the steam condensing within and heating the water which it forces along.

Inlet, Valve: The valve which controls the inlet port and so allows or prevents mixture from passing to the cylinder.

Inlet Port: Passage or entrance in the cylinder wall through which the fuel mixture is taken. Sometimes called intake port.

Inlet Manifold: Sometimes called intake manifold or header. A branched pipe connected to the mixing chamber at one end and at the branch ends to the cylinders so as to communicate with the inlet ports.

Inlet Manifold, Integral: A manifold or header cast integral with the cylinder.

Inner-Tire Shoe: A piece of leather or rubber placed within the tire to protect the inner tube.

Inner Tube: A soft air-tight tube of nearly pure rubber, which fits within a felloe upon the casing.

Inside Lap: See "Exhaust Lap".

Intake Manifold: The large pipe which supplies the smaller intake pipes from each cylinder of a gas engine.

Intake Pipe: Sometimes made synonymous with inlet manifold. Correctly, the pipe from the carbureter to the inlet manifold.

Intake Stroke: See "Induction Stroke".

Intensifier: See "Outside Spark Gap".

Intermediate Gear: A gear in a change-speed set between high and low. In a three-speed set it would be second speed. In a four, either second or third.

Intermediate Shaft: See "Shaft, Intermediate".

Internal-Combustion Motor: Any prime mover in which the energy is obtained by the combustion of the fuel within the cylinder.

Internal Gear: See "Gear, Internal".

Interrupter: See "Vibrator".

J

Jack: A mechanism by which a small force exerted over a comparatively large distance is enabled to raise a heavy body. Used for raising the automobile axle to remove the weight from the wheels.

Jacket, Water: A portion of the cylinder casting through which water flows to cool the cylinder.

Jacket Water: The cooling water circulating in a water-cooling system.

Jackshaft: Shaft used in double-chain drive vehicles. Shaft placed transversely in the frame and driving from its ends chains which turn the rear wheels mounted on a dead axle.

Jeantaud Diagram: See "Diagram, Jeantaud".

Joint Knuckle: See "Swivel Joint."

Joule's Law of Gases: See "Gases, Joule's Law of".

Jump Spark: A spark produced by a secondary jump-spark coil.

Jump Spark, Circuit Maker: A mechanically operated switch by which the circuit in a jump-spark ignition system is opened and closed.

Jump-Spark Coil: An electrical transformer and interrupter, consisting of a primary winding of a few turns of coarse wire surrounding an iron core, and a secondary winding consisting of a great number of turns of very fine wire. The condenser is usually combined with this. Also known as *secondary spark coil.*

Jump-Spark Igniter: See "Igniter, Jump-Spark".

Jump-Spark Plug: See "Spark Plug".

Junction Box: A portion of an electric-lighting system to which all wires are carried for the making of proper connections.

Junk Ring: A packing ring used in sleeve-valve motors. It has the same functions as a piston ring. See "Piston Ring".

K

Kerosene: A petroleum product having a specific gravity between 58° and 40° Baumé. It is used as a fuel in internal-combustion engines and can often be used in gasoline engines by starting the engine on gasoline, then switching to kerosene.

Kerosene Burner: A burner especially adapted to use kerosene as a fuel.

Kerosene Engine: An engine using kerosene as fuel.

Key: A semicircular or oblong piece of metal used to hold a member firmly on a revolving shaft so as to prevent the member from rotating.

Key, Baldwin: A key with an oblong section.

Key, Woodruff: A key with a semicircular section.

Keyway: Slot in a rotating member used to hold the key

Kick Switch: Ignition switch mounted so that the driver can operate it with the foot.

Kilowatt: An electrical unit equal to 1000 watts.

Knuckle Joint: See "Swivel Joint".

L

Labor: The jerky operation of an engine. The engine is said to labor when it cannot pull its load without misfiring or jerking.

Lag, Combustion: The time between the instant of the spark occurrence and the explosion.

Lag, Ignition: The time between the instant of spark occurrence and the time at which the spark mechanism producing it begins to act.

Lamp, Trouble: Sometimes called inspection lamp. A small electric bulb carried in a suitable housing, and attached to a long piece of lamp cord. Used for inspecting parts of the car.

Lamp Bulb: The incandescent bulb used in a lamp.

Lamp Bracket: A support for a lamp.

Lamp Lighter: An apparatus for lighting gas lamps by electricity. The lamps are usually so arranged that by pushing the button the gas is turned on and the spark made at the same time.

Landaulet: A type of car which may be used as an open or closed car. The rear portion of the body may be folded down like a top.

Landaulet Body: An automobile body resembling a limousine body, but having a cover fitted to the back, which may be let down, leaving the back open. The top generally extends over the driver.

Lap: To make parts fit perfectly by operating them with an abrasive, such as ground glass, between the rubbing surfaces. To finish.

Lap of Steam Valves: In the slide valve of a steam engine, the amount by which the admission edges overlap the steam port when the valve is central with the cylinder case.

Layshaft: A countershaft or secondary shaft of a gearset operated by the main or shifter shaft.

Lead, or Lead Wire: Any wire carrying electricity.

Lead: In a steam engine the amount by which the steam port is opened when the piston is at the start of its stroke.

Lead Battery: See "Accumulator".

Lead of Igniter: See "Igniter, Lead of".

Lead of Valve: In an engine the amount by which the admission port is opened when the piston is at the beginning of the stroke; according as this is greater or less, the admission of working fluid is varied through several fractions of the stroke.

Lean Mixture: Fuel after leaving the carbureter, which contains too much air in proportion to the gasoline. Sometimes called thin mixture, rare mixture, or weak mixture.

Lever, Brake: See "Brake Lever."

Lever, Change-Speed: Lever by which the different combinations of change gears are made so as to vary the speed of the driving

wheels in relation to the speed of the engine; also called gearshift lever.

Lever, Spark: Lever by which the speed and power of the engine are controlled by adjusting the time of ignition.

Lever, Steering: See "Steering Lever".

Lever, Throttle: A lever by which the speed and power of the engine are controlled by adjusting the amount of mixture admitted to the cylinder.

Lever Lock: An arrangement for locking the gearshift lever in free position so that with the engine running the driving axle will not be driven.

Lift: The distance through which a poppet valve is moved in opening from fully-closed to fully-open position.

Lifting Jack: See "Jack".

Lighting Outfit, Electric: An outfit for electrically lighting an automobile. This usually consists of a dynamo, storage battery, and lamps and switchboard, with the necessary wiring and cut-outs.

Limousine Body: An enclosed automobile body having the front and sides with side doors. The top extends over the seat of the driver.

Liner: One or more pieces of metal placed between two parts so they may be adjusted by varying the thickness of the liner. Sometimes called a shim. Also refers to a tool used for lining up parts.

Liner, Laminated: A liner or shim made in a number of parts, the thickness being varied by removing or adding parts.

Lines of Force: See "Field, Magnetic".

Link Motion: In a steam engine, the name for the arrangement of eccentric rods, links, hangers, and rocking shafts by which the relative motion and position of the slide valves are changed at will, providing for varying rates of expansion of the steam and thus varying the speed for either forward or backward motion.

Live Axle: See "Axle, Live".

Lock, Auto Safety: A device arranged so that it is impossible to start the motor car except by the proper combination or key.

Lock Nut: A nut placed on a bolt immediately behind the main nut to keep the main nut from turning.

Lock Switch: A switch in the ignition circuit so arranged that it can not be thrown on except by the use of a key.

Lock Valve: A valve capable of being secured with lock and key.

Long-Stroke: A gas engine whose stroke is considerably greater than its bore.

Lost Motion: Sometimes called play or backlash. Looseness of space between two moving parts.

Louver: A slit or opening in the side of a hood or bonnet of a motor car. Used to allow air from the draft to escape. A ventilator.

Low Gear: The lowest speed gear. First speed in a change-speed set.

Low-Speed Adjustment: A carbureter adjustment which regulates the mixture when the motor is operating slowly, with little throttle opening.

Low-Speed Band: The brake or friction band which controls the low speed of a planetary change-speed set.

Low-Tension Current: A current of low voltage or pressure, such as is generated by dry cells, storage battery, or low-tension magneto.

Low-Tension Ignition: See "Ignition, Make-and-Break".

Low-Tension Magneto: A magneto which initially generates a current of low voltage.

Low-Tension Winding: The winding of a transformer or induction coil through which the primary or low-tension current flows.

Low Test: Gasoline which has a high density, thus giving a low reading on the Baumé scale. Low-grade gasoline.

Low-Water Alarm: An automatic arrangement by which notice is given that the water in the boiler is becoming too low for safety.

Lubricant: An oil or grease used to diminish friction in the working parts of machinery.

Lubrication: To supply to moving parts and their bearings grease, oil, or other lubricant for the purpose of lessening friction.

Lubrication, Circulating: A system in which the same oil is used over and over.

Lubrication, Constant-Level: A system in which the level in the crankcase is kept to a predetermined level by means of a pump.

Lubrication, Force-Feed: Method of lubricating the moving parts of an engine by forcing the oil to the points of application by means of a pump.

Lubrication, Gravity: Method of supplying oil to moving parts of an engine by having a reservoir at a certain height above the highest point to be lubricated and allowing the oil to flow to the points of application by gravity.

Lubrication, Non-Circulating: A system in which the same oil is used but once.

Lubrication, Pressure-Feed: See "Lubri cation, Force-Feed".

Lubrication, Sight-Feed: System of lubrication in which the oil pipe to different points of application is led through a glass tube in plain sight; usually at a point on the dashboard.

Lubrication, Splash: Method of lubricating an engine by feeding oil to the crankcase and allowing the lower edge of the connecting rod to splash into it.

Lubricator: A device containing and supplying oil or grease in regular amounts to the working parts of the machine.

Lubricator, Force-Feed: A pump-like device which automatically forces oil to the moving parts.

M

Magnet: A piece of iron or steel which has the characteristic properties of being able to attract other pieces of iron and steel.

Magnet, Horseshoe: A magnet shaped like the letter U.

Magnet, Permanent: A magnet which when once charged retains its magnetism.

Magnetic Field: See "Field, Magnetic".

Magnetic Spark Plug: A spark plug used in a make-and-break system of ignition in which contact is obtained by means of a magnet.

Magneto: See "Ignition, Magneto".

Magneto: See "Magneto-Electric Generator".

Magneto, Double-Distributor: A magneto with two distributors feeding two sets of spark plugs, two in each cylinder and both sparking at once. See "Ignition, Two-Point."

Magneto, High-Tension: A magneto has two armature windings and requires no outside coil for the generation of high-tension current.

Magneto, Induction: A type of magneto in which the armature and fields are stationary and a rotator or spool-shaped piece of metal is used to break the lines of force.

Magneto, Low-Tension: See "Low-Tension Magneto".

Magneto, Rotating Armature: A magneto in which the armature winding revolves.

Magneto Bracket: A shelf or portion of the crankcase web used to support the magneto.

Magneto Coupling: A flexible joint which connects the magneto with a revolving motor shaft.

Magneto Distributor: See "Distributor".

Magneto-Electric Generator: A machine in which there are no field magnet coils, the magnetic field of the machine being due to the action of permanent steel magnets. Usually contracted to *magneto.*

Main Bearing: A bearing used for supporting the crankshaft.

Manifold: A main pipe or chamber into which or from which a number of smaller pipes lead to other chambers. See "Intake Manifold", "Exhaust Manifold", and "Inlet Manifold".

Manometer: A device for indicating either the velocity or the pressure of the water in the cooling system of a gasoline motor.

Master Vibrator: A single vibrator which interrupts the current to each of a set of several spark coils in order.

Mean Effective Pressure: The average pressure exerted upon a piston throughout its stroke.

M. E. P.: Abbreviation for *mean effective pressure.*

Mercury Arc Rectifier: A mercury vapor converter. See "Mercury Vapor Converter".

Mercury Vapor Converter: An apparatus for converting alternating current into direct current by means of a bubble of mercury in a vacuum. The vapor of mercury possesses the property of allowing the flow of current in one direction only. Its principal use is for charging storage batteries.

Mesh: Two gears whose teeth are so positioned that one gear will drive the other are said to be in mesh.

Misfire: Failure of the mixture to ignite in the cylinder; usually due to poor ignition or poor mixtures.

Miss: The failure of a gas engine to explode in one or more cylinders. Sometimes called misfiring.

Mixing Chamber: A pipe or chamber placed between the carbureter and inlet manifold. Sometimes integral with the carbureter or manifold.

Mixing Tube: A tubular carbureter for a gas or gasoline engine.

Mixing Valve: A device through which air and gas are admitted to form an explosive mixture. The carbureter of a gasoline engine combines the mixing valve and vaporizer.

Mixture: The fuel of a gas engine, consisting of sprayed gasoline mixed with air.

Monobloc: Cast *en bloc* or in one piece. Refers usually to cylinders, which are cast two or more at once.

Motocycle: A trade name for a special make of motorcycle.

Motor, Electric: See "Electric Motor".

Motor, Gasoline: See "Gasoline Motor".

Motor, High-Speed: A gas engine whose rotative speed is very high and whose power output goes up with the speed to an unusual degree.

Motor, Horizontal: A gas engine whose cylinder axis lies in a horizontal plane.

Motor, I-head: A gas engine which has cylinders, a section of which resembles the letter I. This type has the valves in the head.

Motor, L-Head: A gas engine in which a section of cylinders resembles the letter L. The valves in this type are all on one side.

Motor, Long-Stroke: See "Long-Stroke Motor".

Motor, Non-Poppet: A gas engine whose valves are not of the poppet type. In this class is the Knight sleeve valve, the rotary valve, and the piston valve.

Motor, Overhead Valve: A motor with cylinders whose valves are in the head.

Motor, Piston Valve: A gas engine using valves which are in the form of pistons.

Motor, Poppet: A gas engine using poppet-type valves. See "Poppet Valve".

Motor, Revolving Cylinder: A motor whose cylinders revolve as a unit.

Motor, Rotary Valve: One in which the valves consist of slots cut out along cylindrical rods which rotate in the cylinder casting.

Motor, Sliding Sleeve: The Knight type motor in which thin sleeves slide up and down in the cylinder, the sleeves having ports which register with the inlet and exhaust manifolds.

Motor, T-Head: A gas engine with the valves on opposite sides of the cylinders, a section of which resembles the letter T.

Motor, V-Type: A motor whose cylinders are set on the crankcase so as to form an angle of 45 to 90 degrees between them.

Motor, Vertical: A motor with the cylinder axis in a vertical plane.

Motorcycle: A bicycle propelled by a gasoline engine.

Mud Guard: Metal or leather strips placed over the wheels to catch the flying mud and to prevent the clothing from coming in contact with the wheels when entering and leaving the car.

Muffler Cut-Out: See "Cut-Out, Muffler".

Muffler Cut-Out Pedal: See "Cut-Out Pedal".

Muffler Exhaust: A vessel containing partitions, usually perforated with small holes and designed to reduce the noise occasioned by the exhaust gases of an engine, by forcing the gases to expand gradually.

Muffler Explosion: Explosion of unburned gases in exhaust passages of the muffler, usually due to poor ignition or poor mixture.

Multiple Circuit: A compound circuit in which a number of separate sources or electrically operated devices, or both, have all their positive poles connected to a single positive conductor and all their negative poles to a single negative conductor.

N

N.A.A.M.: Abbreviation for National Association of Automobile Manufacturers.

Naphtha: A product of the distillation of petroleum used to some extent for marine engines.

Needle Valve: A valve in a carbureter used for regulating the amount of gasoline to flow in with the mixture.

Negative Plate: Plate of a storage battery to which current returns from the outside circuit.

Negative Pole: That pole of an electric source through which the current is assumed to enter or flow back into the source after having passed through the circuit external to the source.

Neutral Position: The position of the change-speed lever which so places the gears that the motor may run idle, the car remaining still.

Non-Deflatable Tire: See "Tire, Non-Puncturable".

Non-Freezing Solution: A solution placed into the radiator of a motor car to prevent the water therein from freezing. Alcohol and glycerine are the usual anti-freezing agents. See "Anti-Freezing Solution".

Non-Puncturable Tire: See "Tire, Non-Puncturable".

Non-Skid Device: See "Anti-Skid Device".

O

Odometer: (1) The mileage-recording mechanism of a speedometer. (2) An instrument to be attached to an automobile wheel to automatically indicate the distance traveled.

Odometer, Hub: A speed-recording device which is placed on the hub cap of a wheel.

Offset: Off center, as a crankshaft in which a line vertically through the crankpins does not coincide with a line vertically through the center of the cylinder.

Ohm: (1) Unit of electrical resistance. (2) Amount of electrical resistance. Such resistance as would limit the flow of electricity under an electromotive force of one volt to a current of one ampere.

Ohm's Law: The law which gives the relation between voltage, resistance, and current flow in any circuit. Expressed algebraically, $C=\frac{I}{R}$ where C is the current flowing in amperes, I the voltage and R the ohmic resistance.

Oil Burner: A burner equipped with an atomizer for breaking up liquid fuel into a spray.

Oil Engine: An internal-combustion motor using kerosene or other oil as fuel.

Oil Gage: (1) A gage to indicate the flow of oil in the lubricating system. (2) Used to show the level of oil in a compartment in the base of a gas engine.

Oil Gun: A cylinder with a long point and a spring plunger for squirting oil or grease into inaccessible parts of a machine.

Oil Pump: A small force pump providing a constant positive supply of oil under pressure; usually considered to be more reliable than a lubricator.

Oiler: An automobile device for oiling machinery.

Opposed Motor: A gasoline engine whose cylinders are arranged in pairs on opposite sides of the crankshaft, both connecting rods of each pair being connected to the same crank, so that the shock of the explosion in one will be balanced by the cushioning effect of the compression in the other. In general these motors are two-cylinder, horizontal.

Otto Cycle: See "Four-Stroke Cycle".

Outside Spark Gap: See "Spark Gap, Outside".

Overcharged: The state of the storage battery when it has been charged at too high a rate or for too great a length of time.

Overhead Camshaft: A camshaft which is placed above the cylinder of a gas engine.

Overhead Valves: See "Motor, Overhead Valve".

Overheating: The act of allowing the motor to reach an excessively high temperature due to the heat of combustion being not carried away rapidly enough by the cooling devices, or to insufficient lubrication. Overheating of a bearing is due to insufficient lubrication.

P

Packing: The material introduced between the parts of couplings, joints, or valves, to prevent the leakage of gas or liquids to or from them.

Panel, Charging: A small switchboard for charging a storage battery.

Parallel Circuit: See "Multiple Circuit".

Patch, Tire-Repair: Rubber strips for making repairs in punctured or ruptured tires.

Petcock: A control cock which when open allows gas or liquid to escape from the chamber to which it is attached.

Petrol: Word used in England for gasoline.

Picric Acid: Acid which may be added to gasoline to increase the motor efficiency. Gasoline will absorb about five per cent of its weight of picric acid.

Pin, Taper: A conically shaped pin.

Pinch: A cut in an inner tube caused by the tube being caught or pinched between the outer casing and the rim.

Pinion: (1) The smaller of any pair of gears. (2) A small gear made to run with a larger gear.

Piston: The hollow, cylindrical portion attached to the connecting rod of a motor. The reciprocating part which takes the strain caused by the explosion.

Piston Air Valve: A secondary air valve in the piston of earlier types of gas engines to compensate the imperfect operation of surface carbureters used with those engines and to secure the injection of a sufficient quantity of air to insure the combustion of the charge.

Piston Head: The top of the piston.

Piston Pin: A pin which holds the connecting rod to the piston.

Piston Ring: (1) A metal ring inserted in a groove cut into a piston assisting in making the latter tight in the cylinder. There are usually three rings on each piston. (2) Rings about the circumference of a piston, whose diameter is slightly greater than that of the piston. These are to insure closer fit and prevent wearing of the piston, as the wear is taken up by the rings which may be easily removed.

Piston Rod: Usually called connecting rod. The rod which connects the piston with the crankshaft.

Piston Skirt: The portion of a piston below the piston pin.

Piston Speed: The rate at which the piston travels in its cylinder.

Piston Stroke: The complete distance a piston travels in its cylinder.

Pitted: Condition of a working surface which has become covered with carbon particles which have been imbedded in the metal.

Planetary Gear: An arrangement of spur and annular gears in which the smaller gears revolve around the main shaft as planets revolve around the sun.

Planetary Transmission: A transmission system in which the speed changes are obtained by a set of planetary gears.

Plate: Part of a storage battery which holds active material. See "Negative Plate".

Pneumatic Tire: A tire fitted to the wheels of automobiles, consisting usually of two tubes, the outer of India rubber, canvas, and other resilient wear-resisting material, and the inner composed of nearly pure rubber which is inflated with compressed air to maintain the outer tube in its proper form under load.

Polarizing: Formation of gas at the negative element of a cell so as to prevent the action of the battery. This formation of gas is caused by the violent reaction taking place in a circuit of low resistance.

Pole Piece: A piece of iron attached to the pole of a magneto used in an electric generator.

Poppet Valve: A disk or drop valve usually seating itself through gravitation or by means of springs, and frequently opening by suction or cams.

Port: An opening for the passage of the working fluid in an engine.

Portable Garage: See "Garage, Portable".

Positive Connection: A connection by which positive motion is transmitted by means of a crank, bolt, or key, or other method by which slipping is eliminated.

Positive Motion: Motion transmitted by cranks or other methods in which slipping is eliminated.

Positive Plate: Plate in a storage battery, from which the current flows to the outside circuit.

Positive Pole: The source from which electricity is assumed to flow; the opposite of negative pole. In a magnet the positive pole is the end of the magnet from which the magnetic flux is assumed to emanate.

Pounding in Engine: Pounding noise at each revolution, usually caused by either carbon deposit, loose or tight piston, loose bearing or other part, or pre-ignition.

Power Stroke: The piston stroke in a gas engine in which the exploded gases are expanding, thus pushing the piston downward.

Power Tire Pump: A pump which is operated by a gas engine and is used to inflate the tires of a motor car.

Power Unit: The engine with fuel, cooling, lubrication, and ignition systems, without the transmission or running gears. Sometimes the gearset and driving shaft are included by the term.

Pre-Ignition: See "Premature Ignition".

Premature Ignition: Ignition of fuel before the proper point in the cycle.

Pressure-Feed: See "Lubrication, Force-Feed".

Pressure Gage: A gage for indicating the pressure of a fluid confined in a chamber, such as steam in a boiler, etc.

Pressure Lubricator: A lubricating device in which the oil is forced to the bearings by means of a pump or other device for maintaining pressure.

Pressure Regulator: A device for maintaining the pressure of the steam in the principal pipe at a constant point irrespective of the fluctuations of pressure in the boiler.

Primary Air Inlet: The main or fixed air intake of a carbureter.

Primary Circuit: The circuit which carries low-tension current.

Primary Coil: A self-induction coil consisting of several turns of wire about an iron core.

Primary Spark Coil: An induction coil which has only a single winding composed of a few layers of insulated copper wire wound on a bundle of soft iron wires, known as the *core*, also as a *wipe*, or *touch*, *spark coil*.

Primer: A pin in a float-feed valve so arranged that it may depress the float in priming a gasoline engine. Also called *tickler* and *flushing pin*.

Priming: (1) The carrying of water over with the steam from the boiler to the engine, due to dirty water, irregular evaporation, or forced steaming. (2) Injecting a small amount of gasoline into the cylinder of a gasoline engine to assist in starting.

Priming Cock: A control cock screwed into the cylinder and which when open communicates with the combustion chamber allowing gasoline to be poured into the cylinder.

Progressive Change-Speed Gears: Change-speed gears so arranged that higher speeds are obtained by passing through all the intermediate steps and *vice versa*.

Prony Brake: A dynamometer to indicate the horsepower of an engine. A band encircles the flywheel of the engine and is secured to a lever, at the other end of which is a scale to measure the pull.

Propeller Shaft: The shaft which turns the rear axle of a motor car. The drive shaft.

Pump, Centrifugal: A pump with a hollow hub and curved blades which by centrifugal force throw water or oil into the system requiring it.

Pump, Circulation: See "Circulation Pump".

Pump, Fuel-Feed: A mechanically operated pump for insuring positive feed of fuel to the burner of a steam engine or carbureter of a gas engine.

Pump, Oil: See "Oil Pump".

Pump, Plunger: Sometimes called piston pump. One containing a piston which forces a liquid to a system.

Pump, Power Tire: See "Tire Pump".

Pump, Steam Boiler-Feed: See "Boiler-Feed Pump".

Pump, Water Circulating: See "Circulation Pump".

Pump Gear: A pump composed of two gears in mesh placed in a housing. When the gears revolve they carry oil or water, as the case may be, on their teeth, which deliver it to an outlet.

Puncture: The perforation of an inflated rubber automobile tire by some sharp substance on the roadbed.

Puncture-Closing Compound: A viscous compound placed within the inner tire tube to close the hole caused by a puncture.

Push Rod: A rod which operates the valves of a poppet-valve motor. A rod which imparts a pushing motion.

R

Race: (1) The parts upon which the balls of a ball bearing roll. (2) When referring to a gas engine, to operate at high speed without a load.

Racing Body: A low, light automobile body, having two seats with backs as low as possible; designed for large fuel capacity and very high speed.

Radiator: A device consisting of a large number of small tubes, through which the heated water from the jacket of the engine passes to be cooled, the heat being carried away from the metal of the radiator by air.

Radiator, Cellular: See "Honeycomb Radiator".

Radiator, Tubular: A radiator consisting of many tubes, through which water passes to be cooled.

Radiator Protector: See "Bumper".

Radius Rod: A bar in the frame of an automobile to assist in maintaining the proper distance between centers. Also called *distance rod.*

Rawhide Gear: Tooth gears, built up of compressed rawhide, used for high-speed drive. Sometimes a metal gear is merely faced with rawhide for the purpose of reducing noise.

Reach Rod: See "Radius Rod".

Reciprocating Parts: The parts such as pistons and connecting rods which have a reciprocating motion.

Rectifier, Alternating-Current: See "Current Rectifier".

Relief Cock: See "Compression-Relief Cock".

Removable Rim: See "Demountable Rim".

Resiliency: That property of a material by virtue of which it springs back or recoils on removal of pressure, as a spring.

Resistance, Electrical: (1) A part of an electric circuit for the purpose of opposing the flow of the current in the circuit. (2) The electrical resistance of a conductor is that quality of a conductor by virtue of which the conductor opposes the passage of electricity through its mass. Its unit is the *ohm.*

Retard: With reference to the ignition system, causing the spark to occur while the piston is retarding or moving downward on the working stroke.

Retarding Ignition: See "Ignition, Retarding".

Retarding the Spark: See "Ignition, Retarding".

Retread: To replace the tread of a pneumatic tire with a new one.

Reverse Cam: On a gasoline engine a cam so arranged that by reversing its motion or shifting it along its shaft it will operate the valves and cause the engine to reverse.

Reverse Gear: In a steam engine, a device by which the valves may be set to effect motion of the car in either direction. In a gasoline automobile, the reversing gear is usually incorporated with the change-speed gears.

Reverse Lever: A lever by which the direction of movement of the driving wheels may be reversed without reversing the engine. This is usually combined with the change-speed levers.

Rheostat: A device for regulating the flow of current in a closed electrical circuit by introducing a series of graduated resistances into the circuit.

Rim: The portion of a wheel to which a solid or pneumatic tire is fitted. A circular, channel-shaped portion attached to the wheel felloe.

Rim, Demountable: A rim which may be removed from the wheel easily in order that another with an inflated tire may take its place.

Rim, Quick-Detachable: A rim made of two or more parts so that the tire may be detached and attached quickly.

Rim, Removable: See "Demountable Rim".

Road Map: A map of a section or locality showing the best roads for motor-car travel, and usually the best stopping places and repair stations.

Roadster: A small motor car designed to be fairly speedy; usually has carrying capacity for an extra large quantity of fuel and supplies; generally seats two persons, with provision for one or two more, by the attachment of a rumble seat in the rear.

Rocker Arm: A pivoted lever used to operate overhead valves in a T-head motor.

Rod, Radius: See "Radius Rod".

Rod, Steering: See "Steering Rod".

Roller Bearings: See "Bearing, Roller".

Roller Chain: A chain whose links are provided with small rollers to decrease the friction and the noise.

Rotary Valve: A type of valve somewhat similar to the Corliss engine valve used on automobile motors.

Rumble: A small single seat to provide for an extra passenger on a two-seated vehicle. Usually detachable.

Runabout: A small two-seated vehicle, usually of a lower power and lower speed, as well as lower operating radius, than a roadster.

Running Board: A horizontal step placed below the frame and used to assist passengers in leaving and entering a motor car.

Running Gear: The frame, springs, motor, wheels, speed-change gears, axles, and machinery of an automobile, without the body; used synonymously with *chassis*.

S

Safety Plug: See "Fusible Plug".

Safety Valve: A valve seated on the top of a steam boiler, and loaded so that when the pressure of the steam exceeds a certain point the valve is lifted from the seat and allows the steam to escape.

Saturated Steam: The quality of the steam when no more steam can be made in the closed vessel without raising the temperature or lowering the pressure.

Scavenging: The action of clearing the cylinder of an internal-combustion motor of the burned-out gases.

Score: To burn, or abrade a moving part with another moving part.

Screw: An inclined plane wrapped around a cylinder; a cylinder having a helical groove cut in its surface.

Searchlight: A headlight designed to throw a very bright light on the road. Electricity or acetylene is usually used as an illuminant, and the lamp has a parabolic reflector and may be turned to throw the light in any direction.

Secondary Battery: See "Accumulator".

Secondary Current: A current in which the electromotive force is generated by induction from a primary circuit in which a variable current is flowing. The high-tension current of a jump-spark ignition system.

Secondary Circuit: The circuit which carries high-tension current.

Secondary Spark Coil: An induction coil having a double winding upon its core. The inner winding is composed of a few layers of insulated wire of large size, and the outer winding consists of a great many layers of very small insulated copper wire. Also known as a *jump-spark coil*.

Seize: Refers to moving parts which adhere because of operation without a film of oil between the working surfaces.

Selective Change-Speed Gears: Change-speed gears so arranged that any desired speed combination can be obtained without going through the intermediate steps.

Self-Firing: Ignition of the mixture in a gas engine due to the walls of the cylinder or particles attached to them becoming overheated and incandescent.

Self-Starter: See "Engine Starter".

Separator, Steam: A device attached to steam pipes to separate entrained water from live steam before it enters the engine, or to separate the oily particles from exhaust steam on its way to the condenser.

Series Circuit: A compound circuit in which the separate sources or the separate electrical receiving devices, or both, are so placed that the current supplied by each, or passed through each, passes successively through the other circuits from the first to the last.

Set Screw: A small screw with a pointed end used for locking a part in a fixed position to prevent it from turning.

Setting Valves: See "Valve Setting".

Shaft, Intermediate: The shaft placed between the first and third motion gearing and acting as a carrier of motion between the two.

Shaft Drive: System of power transmission by means of a shaft.

Shim: See "Liner".

Shock Absorber: A device attached to the springs or hangers of motor cars to decrease the jars due to rough roads, instead of allowing them to be transmitted to the frame of the carriage.

Short Circuit: A shunt or by-path of comparatively small resistance around a portion of an electric circuit, by which enough current passes through the new path to virtually cut out the part of the circuit around which it is passed, and prevent it from receiving any appreciable current.

Sight Feed: An indicator covered with glass which shows that oil is flowing in a system. A telltale sight. A check on the oiling system.

Side-Bar Steering: See "Steering, Side-Bar".

Side-Slipping: See "Skidding".

Silencer: See "Muffler, Exhaust".

Silent Chain: A form of driving chain in which the links are comprised of sections which so move over the sprocket that practically all noise is eliminated. Silent chains are used specially for driving timing gears, gearsets, etc.

Skidding: The tendency of the rear wheels to slide sideways to the direction of travel, owing to the slight adhesion between tires and the surface of the roadbed, also called *side-slipping*.

Skip: See "Miss".

Sleeve Valve: A form of valve consisting of cylindrical shells moving up and down in the cylinders of such a motor as the Silent Knight.

Sliding Gears: A change-speed set in which various gears are placed into mesh by the sliding on a shaft of one or more gears.

Sliding Sleeve: See "Motor, Sleeve-Valve".

Slip Cover: A fabric covering for the top when down or for the upholstery of a motor vehicle.

Smoke in Exhaust: Smoky appearance in the exhaust due to too much oil, too rich mixture, low grade of fuel, or faulty ignition.

Solid Tire: See "Tire, Solid".

Sooting of Spark Plug: Fouling of the spark plug with soot, due to poor mixture, impure fuel, or improper lubrication.

Spare Wheel: An extra wheel complete with inflated tire, carried on the car for quick replacement of wheel with damaged tire.

Spark, Advancing: See "Advanced Ignition".

Spark Coil: A coil or coils of wire for producing a spark at the spark plug. It may be either a secondary or primary spark coil.

Spark Gap: A break in the circuit of a jump-spark ignition system for producing a spark within the cylinder to ignite the charge. The spark gap is at the end of a small plug called the *spark plug*.

Spark Gap, Extra: See "Spark Gap, Outside".

Spark Gap, Outside: A device to overcome the short circuiting in the spark gap due to fouling and carbon deposits between the points of the high-tension spark plug. It is a form of condenser, or capacity in which the air acts as the dielectric between two surfaces at the terminals of a gap in a high-tension circuit.

Spark Intensifier: See "Spark Gap, Outside".

Spark Lever: See "Timing Lever".

Spark Plug: The terminals of the secondary circuit of a jump-spark ignition system mounted to leave a spark gap between the terminals projecting inside the cylinder for the purpose of igniting the fuel in the cylinder by means of a spark crossing the gap between them.

Spark Plug, Pocketing: Mounting the spark plug in a recess of the cylinder head to reduce the sooting of the sparking points.

Spark Plug, Sooting of: See "Sooting of Spark Plug".

Spark Regulator: A mechanism by which the time of ignition of the charge is varied by a small handle on or near the steering wheel.

Spark, Retarding: See "Ignition, Retarding".

Spark Timer: See "Timer, Ignition".

Speaking Tube: See "Annunciator".

Specific Gravity: The weight of a given substance relative to that of an equal bulk of some other substance which is taken as a standard of comparison. Air or hydrogen is the standard for gases, and water is the standard for liquids and solids.

Specific Heat: The capacity of a substance for removing heat as compared with that of another which is taken as a standard. The standard is generally water.

Speed-Change Gear: A device whereby the speed ratio of the engine and driving wheels of the car is varied.

Speed Indicator: An instrument for showing the velocity of the car.

Speedometer: A device used on motor cars for recording the miles traveled and for indicating the speed at all times.

Speedometer Gears: Gears used to drive a shaft which operates the speedometer.

Speedometer Shaft: A flexible shaft which operates a speedometer.

Spiral Gear: A gear with helically-cut teeth.

Splash Lubrication: See "Lubrication, Splash".

Spline: A key.

Spontaneous Ignition: See "Self-Firing".

Sprag: A device to be let down (usually at the rear of the car) to prevent its slipping back when climbing a hill.

Spray Nozzle: That portion of a carbureter which sprays the gasoline.

Spring: An elastic body, as a steel rod, plate, or coil, used to receive and impart power, regulate motion, or diminish concussion.

Spring, Cantilever: A type of spring which appears like a semi-elliptic reversed; and which is flexibly attached in the center, rigidly at one end, and by a shackle at the other.

Spring, Elliptic: A spring, elliptic in shape, and consisting of two half-elliptic members attached together.

Spring Semi-Elliptic: A spring made up of a number of leaves, the whole resembling a portion of an ellipse.

Spring, Supplementary: See "Shock Absorber".

Spring, Underslung: A spring which is fastened under the axle instead of over it.

Spring Hangers: See "Body Hangers".

Spring Shackle: A link attached to one end of a spring which allows for flattening of the spring.

Sprocket: A wheel with teeth around the circumference, so shaped that the teeth will fit into the links of a chain which drives or is driven by the sprocket.

Starboard: The right-hand side of a ship or vessel.

Starter, Engine: See "Engine Starter".

Starting, Gas Engine: The operation necessary to make the engine automatically continue its cycle of events. It usually consists of opening the throttle, retarding the spark, closing the ignition circuit, and cranking the engine.

Starting Crank: A crank by which the engine may be given several revolutions by hand in order to start it.

Starting Device: See "Engine Starter".

Starting on Spark: In engines having four or more cylinders with well-fitting pistons, it is often possible to start the motor after it has stood idle for some time by simply closing the ignition circuit, provided that the previous stopping of the engine was done by opening the ignition circuit before the throttle was closed, leaving an unexploded charge under compression in one of the cylinders.

Steam: The vapor of water; the hot invisible vapor given off by water at its boiling point.

Steam Boiler: See "Boiler".

Steam Condenser: See "Condenser".

Steam, Cycle of: A series of operations of steam forming a closed circuit, a fresh series beginning where another ends; that is, steam is generated in the boilers, passes through the pipes of the engine, doing work successively in its various cylinders, escaping at exhaust pressure to the condenser, where it is converted into water and returned to the boiler, to go through the same operations once more.

Steam Engine: A motor depending for its operation on the latent energy in steam.

Steam Gage: See "Pressure Gage".

Steam Port: See "Admission".

Steering, Side-Bar: Method of guiding the car by means of an upright bar at the side of the seat.

Steering Angle for Front Wheels: Maximum angle of front wheels to the axle when making a turn; should be about 35°.

Steering Check: A device for locking the steering gear so that the direction will not be changed unless desired.

Steering Column: See "Steering Post".

Steering Gear: The mechanism by which motion is communicated to the front axle of the vehicle, by which the wheels may be turned to guide the car as desired.

Steering Knuckle: A knuckle connecting the steering rods with the front axle of the motor.

Steering Lever: A lever or handle by which the car is guided.

Steering Neck: The vertical spindle carried by the steering yoke. It is the pivot of the bell crank by which the wheel is turned.

Steering Pillar: See "Steering Post".

Steering Post: The member through which the twist of the steering wheel is transmitted to the steering knuckle. The steering post often carries the spark and throttle levers also.

Steering Rod: The rod which connects the steering gear with the bell cranks or pivot arms, by means of which the motor car is guided.

Steering Wheel: The wheel by which the driver of a motor car guides it.

Steering Yoke: The Y-shaped piece in which the front axle terminates. The yoke carries the vertical steering spindle or steering neck.

Stephenson Link Motion: A reversing gear in which the ends of the two eccentric rods are connected by a link or quadrant sliding over a block at the end of the valve spindle.

Step-Up Coil: A coil used to transform low- into high-tension current.

Storage Battery: See "Accumulator".

Stroke: See "Piston Stroke".

Strainer, Gasoline: A wire netting for preventing impurities entering the gasoline feed system.

Strangle Tube: The narrowing of the throat of the carbureter just above the air inlets in order to increase the speed of the air, and thus increase the proportion of gas which will be picked up.

Stroke: The distance of travel of a piston from its point of farthest travel at one end of the cylinder to its point of farthest travel at the other end. Two strokes of the piston take place to every revolution of the crankshaft.

Stud Plate: The plate or frame in a planetary transmission system carrying studs upon which the central pinions revolve.

Suction Valve: The type of admission valve on an internal combustion engine which is opened by the suction of the piston within the cylinder and admits the mixture. The valve is normally held to its seat by a spring.

Sulphating of Battery: The formation of an inactive coating of lead sulphate on the surface of the plates of a storage battery. It is a source of loss in the battery.

Superheated Steam: Steam which has been still further heated after reaching the point of saturation.

Supplementary Air Valve: See "Auxiliary Air Valve".

Swivel Joint: The joint for connecting the steering arm of the wheel or lever-steering mechanism to the arms on the steering wheel. Also called *knuckle joint.*

T

Tachometer: An instrument for indicating the number of revolutions made by a machine in a unit of time.

Tandem Engine: A compound engine having two or more cylinders in a line, one behind the other, and with pistons attached to the same piston rod.

Tank Gage: See "Fuel-Level Indicator".

Tappet Rod: See "Push Rod".

Taxicab: A public motor-driven vehicle in which the fare is automatically registered by the taximeter.

Taximeter: An instrument in a public vehicle for mechanically indicating the fare charged.

Terminals: The connecting posts of electrical devices, as batteries or coils.

Thermal Unit:* Usually called the *British Thermal Unit*, or *B. t. u.* A measure of mechanical work equal to the energy required to raise one pound of water one degree Fahrenheit.

Thermostat: An instrument to automatically regulate the temperature.

Thermosiphon Cooling: A method of cooling the cylinder of a gas engine. The water rises from the jackets and siphons into a radiator from whence it returns to the supply tank, doing away with the necessity for a circulating pump.

Three-Point Suspension: A method used for suspending motor car units, such as the motor, on three points.

Throttle: A valve placed in the admission pipe between the carbureter and the admission valve of the motor to control the speed and power of the motor by varying the supply of the mixture.

Throttle, Foot: See "Accelerator".

Throttle, Lever: A lever on the steering wheel which operates the carbureter throttle. See "Throttle".

Throttling: The act of closing the admission pipe of the engine so that the gas or steam is admitted to the cylinder less rapidly, thus cutting down the speed and power of the engine.

Thrust Bearing: A bearing which takes loads parallel with the axis of rotation of the shaft upon which it is fitted.

Tickler: A pin in a carbureter arranged to hold down the float in priming, also called *flushing pin* and *primer.*

Timer, Ignition: An ignition commutator.

Timing Gears: The gears which operate the camshaft and magneto shaft. The camshaft gear is twice as large as the crankshaft gear.

Timing Lever: A lever fitted to gas engines by means of which the time of ignition is changed. Also called *spark lever.*

Timing Valve: In a gas engine using float-tube ignition, a valve controlling the opening between the combustion space and the igniter.

Tip, Burner: A small earthen, aluminum, or platinum cover for the end of the burner tube of an acetylene lamp. It is usually provided with two holes, so placed that the jets from them meet and spread out in a fan shape.

Tire, Airless: See "Airless Tire".

Tire, Clincher: A type of pneumatic tire which is held to a clincher.

Tire, Cushion: Vehicle tire having a very thick rubber casing and very small air space. It is non-puncturable and does not have to be inflated, but is not as resilient as a pneumatic tire.

Tire, Non-Deflatable: See "Tire, Non-Puncturable".

Tire, Non Puncturable: A tire so constructed that it cannot be easily punctured or will not become deflated when punctured.

Tire, Punctures in: Holes or leaks in pneumatic tires caused by foreign substances penetrating the inner tube and allowing the air to escape.

Tire, Single-Tube: A pneumatic tire in which the inner and outer tubes are combined.

Tire, Solid: A tire made of solid, or nearly solid rubber.

Tire Band: A band to protect or repair a damaged pneumatic tire. See "Tire Protector".

Tire Bead: Lower edges of a pneumatic tire which grip the curved portion of a rim.

Tire Case: (1) A leather or metal case for carrying spare tire; same as *tire holder.* (2) The outer tube.

Tire Chain: See "Anti-Skid Device".

Tire Filling: Material to be introduced into the tire to take the place of air and do away with puncture troubles

Tire Gage: Gage used for measuring the air pressure in a pneumatic tire.

Tire Holder: A metal or leather case for carrying spare tires.

Tire-Inflating Tank: A tank containing compressed air or gas for inflating the tires.

Tire Inflater, Mechanical: A small mechanical pump for inflating pneumatic tires.

Tire Patch: See "Patch, Tire Repair".

Tire-Pressure Gage: A pressure gage to indicate the pressure of air in the tire.

Tire Protector: The sleeve or band placed over a tire to protect it from road wear.

Tire Pump: A pump for furnishing air under pressure to the tire, may be either hand- or power-operated.

Tire Sleeve: A sleeve to protect the injured part of a pneumatic tire. It is a tire protector which covers more of the circumference of the wheel than a tire band. See "Tire Protector".

Tire Tape: Adhesive tape used to bind the outer tube to the rim in repairing tires.

Tire Tool: Tool used to apply and remove a tire.

Tire Valve: A small valve in the inner tube to allow air to be pumped into the tube without permitting it to escape.

Tires, Creeping of: See "Creeping of Tires".

Tonneau: The rear seats of a motor car. Literally, the word means a round tank or water barrel.

Torque: Turning effort, or twisting effort of a rotating part.

Torque Rod: A rod attached at one end to the rear axle and at the other to the frame; used to prevent twisting of the rear-axle housing.

Torsion Rod: The shaft that transmits the turning impulse from the change gears to the rear axle. Usually spoken of as the *shaft.*

Touch Spark: See "Wipe Spark".

Tourabout: A light type of touring car.

Touring Car: A car with no removable rear seats, and a carrying capacity of four to seven persons.

Town Car: A car having the rear seats enclosed but the driver exposed.

Traction: The act of drawing or state of being drawn. The pull (or push) of wheels.

Tractor: A self propelled vehicle for hauling other vehicles or implements; a traction engine.

Transmission, Individual Clutch: A transmission consisting of a set of spur gears on parallel shafts which are always in mesh, different trains being picked up with a separate clutch for each set.

Transmission, Planetary: A transmission system in which a number of pinions revolve about a central pinion in a manner similar to the revolution of the planets about the sun; usual type consists of a central pinion surrounded by three or more pinions and an internal gear.

Transmission, Sliding Gear: A transmission system in which sliding change-speed gears are used.

Transmission Brake: Brake operating on the gearset shaft or end of the propeller shaft.

Transmission Gears: A set of gears by which power is transmitted. In automobiles, usually called *change-speed gears.*

Transmission Ratio: The ratio of the speed of the crankshaft to the speed of the transmission shaft or driving shaft.

Tread: That part of a wheel which comes in contact with the road.

Tread, Detachable: A tire covering to protect the outer tube, which may be taken off or replaced.

Trembler: The vibrating spring actuated by the induction coil magnet which rapidly connects and disconnects the primary circuit in connection with jump-spark ignition.

Truck: (1) A strong, comparatively slow-speed vehicle, designed for transporting heavy loads. (2) A swiveling carriage having small wheels, which may be placed under the wheels of a car.

Try Cock: A faucet or valve which may be opened by hand to ascertain the height of water in the boiler.

Tube Case: See "Tire Case".

Tube Ignition: See "Hot-Tube Ignition".

Tubing, Flexible: See "Flexible Tubing".

Tubular Radiator: An automobile radiator in which the jacket water circulates in a series of tubes.

Tungsten Lamp: Incandescent bulb with the filament made of tungsten wire.

Turning Moment: See "Torque".

Turning Radius: The radius of a circle which the wheels of a car describe in making its shortest turn.

Turntable: Device installed in the floor of a garage and used for turning motor cars around.

Two-Cycle or Two-Stroke Cycle Engine: An internal-combustion engine in which an impulse occurs at the beginning of every revolution, that is, at the beginning of every downward stroke of the piston.

Two-to-One Gear: The system of gearing in a four-cycle gas engine for driving the camshaft, which must revolve once to every two revolutions of the crankshaft.

U

Under Frame: The main frame of the chassis or running gear of a motor vehicle.

Unit-Power Plant: A power system consisting of a motor, gearset, and clutch which may be removed from the motor car as a unit.

Universal Joint: A mechanism for endwise connection of two shafts so that rotary motion may be transmitted when one shaft is at an angle with the other. Also called *universal coupling, flexible coupling, Cardan joint* and *Hooke's joint.*

Upkeep: The expenditure for maintenance or expenditure required to keep a vehicle in good condition and repair.

V

Vacuum Fuel Feed: A system of feeding the gasoline from a tank at the rear of an automobile by maintaining a partial vacuum at some point in the system, usually at the dash, the fuel flowing from this point by gravity to the carbureter.

Vacuum Line: In an indicator diagram, the line of absolute vacuum. It is at a distance corresponding to 14.7 pounds below the atmospheric line.

Valve: A device in a passage by which the flow of liquids or gases may be permitted or stopped.

Valve, Admission: The valve in the admission pipe of the engine leading from the carbureter to the cylinder by which the supply of fuel may be cut off.

Valve, Automatic: See "Automatic Valve".

Valve, Inlet: See "Inlet Valve".

Valve, Mixing: See "Mixing Valve".

Valve, Muffler Cut-Out: See "Cut-Out, Muffler".

Valve, Overhead: See "Overhead Valve".

Valve, Poppet: See "Poppet Valve".

Valve, Rotary: See "Motor, Rotary Valve".

Valve, Suction: An admission valve which is opened by the difference between the pressures in the atmosphere and in the cylinder.

Valve Cage: A valve-retaining pocket which is attached to the cylinder.

Valve Clearance: The clearance of play between the valve stem and the tappet.

Valve Gear: The mechanism by which the motion of the admission or exhaust valve is controlled.

Valve Grinding: The act of removing marks of corrosion, pitting, etc., from the seats and faces of poppet or disk valves. The surfaces to be ground are rotated in contact with each other, an abrasive having been supplied.

Valve Lift: See "Lift".

Valve Lifter: A device for raising a poppet valve from its seat.

Valve Seat: (1) That portion of the engine upon which the valve rests when it is closed. (2) The portion upon which the face of a valve is in contact when closed.

Valve Setting: The operation of adjusting the valves of an engine so that the events of the cycle occur at the proper time. Also called *valve timing.*

Valve Spring: The spring which is around the valve stem and is used to return the valve to closed position after it has been opened by the cam:

Valve Stem: The rod-like portion of a poppet valve.

Valve Timing: See "Valve Setting".

Vaporizer: A device to vaporize the fuel for an oil engine. In starting it is necessary to heat the vaporizer, but the exhaust gases afterwards keep it at the proper temperature. The carbureter of the gas engine properly belongs under the general head of *vaporizer*, but the term has become restricted to the vaporizer for oil engines.

Variable-Speed Device: See "Gear, Change-Speed".

Vertical Motor: An upright engine whose piston travel is in a vertical plane.

Vibrator: The part of the primary circuit of a jump-spark ignition system by which the circuit is rapidly interrupted to give a transformer effect in the coil.

Vibrator, Master: See "Master Vibrator".

Volatile: Passing easily from a liquid to a gaseous state, in opposition to *fixed.*

Volatilization: Evaporation of liquids upon exposure to the air at ordinary temperatures.

Volt: Practical unit of electromotive force; such an electromotive force as would cause a current of one ampere to flow through a resistance of one ohm.

Voltammeter: A voltmeter and an ammeter combined; sometimes refers to wattmeter.

Voltmeter: An instrument for measuring the difference of electric potential between the terminals of an electric circuit. It registers the electric pressure in volts.

Vulcanization: The operation of combining sulphur with rubber at a high temperature, either to make it soft, pliable, and elastic, or to harden it.

Vulcanizer: A furnace for the vulcanization of rubber.

W

Walking Beam: See "Rocker Arm".

Water Cooling: Method of removing the heat of an internal-combustion motor from the cylinders by means of a circulation of water between the cylinders and the outer casing.

Water Gage: An instrument used to indicate the height of water within a boiler or other water system. It consists of a glass tube connected at its upper and lower ends with the water system.

Water Jacket: A casing placed about the cylinder of an internal-combustion engine to permit a current of water to flow around it for cooling purposes.

Watt: The unit of electric power. It is the product of the current in amperes flowing in a circuit by the pressure in volts. It is $\frac{1}{746}$ of a horsepower.

Watt Hour: The unit of electrical energy. The given watt-hour capacity of a battery, for instance, means the ability of a battery to furnish one watt for the given number of hours or the given number of watts for one hour, or a number of watts for a number of hours such that their product will be the given watt hours.

Welding, Autogeneous: A method of joining two pieces of metal by melting by means of a

blow torch burning acetylene in an atmosphere of oxygen. This melts the ends of the parts and these are then run together.

Wheel, Artillery: A wood-spoked wheel whose spokes are in line with a line drawn vertically through the hub.

Wheel, Dished: A wheel made concave or convex so that the hub is inside or outside as compared with the rim. This is to counteract the outward inclination of the wheel due to the fact that the spindle is tapered and that its outward center is lower than its inner center.

Wheel, Double-Interacting: The mechanism by which two wheels are hung on one hub or axle, the outer being shod with an ordinary solid tire and the inner with a pneumatic tire, so that the weight of the vehicle bears against the lowest point of the pneumatic tire of the inner wheel to give the durability and tractive properties of a solid tire with the resiliency of a pneumatic.

Wheel, Spare: See "Spare Wheel".

Wheel Steering: See "Steering Wheel".

Wheel, Wire: A wheel with spokes made of wire.

Wheel Puller: A device used for pulling automobile wheels from their axles.

Wheel Steer: A method of guiding a car by means of a hand wheel.

Wheel, Steering Angle for: The angle which the steering column makes with the horizontal. It varies from 90° to 30° or less.

Wheelbase: The distance between the road contact of one rear wheel with the point of road contact of the front wheel on the same side.

Wheels, Driving on All Four: The method of using all four wheels of an automobile as the driving wheels.

Wheels, Driving on Front: The method of using the two front wheels as the drivers.

Wheels, Steering on Rear: Method of guiding the vehicle by turning the rear wheels.

Whistle: An automobile accessory consisting of a signalling apparatus giving a loud or harsh sound. Also called a *horn*.

Wind Guard: See "Wind Shield".

Wind Shield: A glass front placed upright on the dash to protect the occupants of the car from the wind.

Wipe Spark: Form of primary sparking device in which a spark is produced by a moving terminal sliding over another terminal, the break thus made causing a spark. Also called *touch spark*.

Wipe-Spark Coil: A primary spark coil with which the spark is made by wiping contact.

Wire Drawing: The effect of steam passing through a partially closed valve or other constricted opening; so called from the thinness of the indicator diagram.

Working Pressure: The safe working pressure of a boiler, usually estimated as $\frac{1}{6}$ of the pressure at which a boiler will burst.

Worm: A helical screw thread.

Worm and Sector: A worm gear in which the worm wheel is not complete but is only a sector. Used especially in steering devices.

Worm Drive: A form of drive using worm gears. See "Gears, Worm".

Worm Gear: The spiral gear in which a worm or screw is used to rotate a wheel

Worm Wheel: A wheel rotated by a worm.

Wrist Pin: See "Piston Pin".

X

X Spring: A vehicle spring composed of two laminated springs so placed one upon the other that they form the letter X.

Y

Yorke, Steering: See "Steering Yoke".

INDEX OF WIRING DIAGRAMS

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GENERAL INDEX

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The page numbers of this volume will be found at the bottom of the pages; the numbers at the top refer only to the section.

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